Two cases in high reliability organizing

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Two Cases in High Reliability Organizing:

a Hermeneutic Reconceptualization

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UNIVERSITEIT VAN TILBURG

Two Cases in High Reliability Organizing:
a Hermeneutic Reconceptualization

Twee Gevalsstudies over Organiseren voor Hoge Betrouwbaarheid:
Een Hermeneutische Reconceptualisatie

PROEFSCHRIFT

ter verkrijging van de graad van doctor aan de Universiteit van Tilburg, op gezag van de rector magnificus, prof. dr. Ph. Eijlander, in het openbaar te verdedigen ten overstaan van een door het college voor promoties aangewezen commissie in de aula van de Universiteit op vrijdag 18 december 2009 om 14.15 uur

door

Gerd Geeraard Paula Van Den Eede

geboren op 7 juni 1970 te Dendermonde, België

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Prof. dr. M. Turoff
Prof. dr. D. Van Lindt

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Glossary and List of Acronyms

Effectiveness	Refers to an absolute level of outcome attainment. Something that is effective works well and produces the results that were intended.
Efficiency	Refers to an input-output ratio or comparison of input (cost, time, effort) and output (result, performance)
Hermeneutics	Hermeneutics is defined as the theory or philosophy of the interpretation of meaning. Several types of hermeneutic research approaches exist, but in this research we adhere to the pragmatic-constructivist approach where interpretation involves entering into the interpretative norms of a community and where meaning operates and is to be found within the historical contexts of the interpreter and interpreted. Understanding works in broadening concentric circles.
HROs	High Reliability Organization – Organizations where the risk of calamity is very high, but that yet are successful in their avoidance and/or mitigation.
HRT	High Reliability Theory – The collection of work on HROs. It is a theory on how a high degree of reliability can be achieved.
IM	Incident Management – The process of handling incidents in an efficient and effective manner.
LCT	Loose Coupling Theory – LCT incorporates a multidimensional perspective to the organizing process by studying the (1) causation, (2) typology, (3) effects, (4) compensations and (5) organizational outcomes of coupling. According to LCT's dialectical perspective on loose coupling 'not tightly coupled' is not the same as 'loosely coupled'. In this sense LCT opposes against the one-dimensional approach to coupling of NAT.
NAT	Normal Accidents Theory – A theory on reliability that posits that accidents are a normal consequence of a system's interactive complexity and tight coupling
SeMa	SenseMaking – The process of creating a mental model of a situation, particularly when this situation is ambiguous.

Preface

Have no fear of perfection
– you'll never reach it.
Salvador Dali

A preface should explain and thank; it has two audiences, those who might be interested in reading the manuscript and those who have made reading possible.

Seventeen years after my graduating as a Master in Commercial Sciences, the goal is to get a PhD. In that time a lot has happened: I got married, became a father of two, changed jobs a few times, made and lost friends and relatives. Professionally I became fascinated by organizations and more specifically by the coordination mechanisms they employ. Coordination is related to organization design and organization behavior which in their turn are all about organization structure, decision making, leadership style, culture etc. Not surprisingly therefore, postmodern science philosophy teaches us that most problems are multidisciplinary. It seems as if no issue can be solved except when tools, techniques or insights from neighboring fields of study are drawn in. As a child of postmodern thought, my field of interest is broad, triggered by a complex observable reality that emphasizes the necessity of taking a broad perspective on things. A doctoral thesis however has little to do with this postmodern view. For a doctoral candidate, the exigencies are not to widen one's knowledge but to deepen it. Instead of getting to know more about more, one is encouraged to learn more about less. Regarding my background and personal interest this represented a conflict: how could I combine a genuine broad interest with the exigencies of a doctoral thesis that forces one to specialize to the extreme? I found the solution by looking not at what is there, but by looking at what is not there. Allow me to explain this a bit further by referring to the house building metaphor. In building a house one needs bricks, lots of them. Some of these bricks are of more interest than others (corner stones, foundation bricks, etc), but all of them are needed to build a house. And the mason knows this. He does not want to find out the details off all the particular types of bricks, for him it is enough that he has a general idea in order to be able to use the bricks to construct the building. He is a generalist, driven by a strong desire to build. The worker in the brick factory or stone quarry is completely different from the mason. He is interested in the particularities of the brick or stone in terms of e.g. absorption capacity, hardness, heat resistance, isolation etc. He specializes in them and is not interested in actually building the house. The mason can be compared to the consultant or manager, the stone specialist to the academic.

Getting back to our idea of looking at what is not there, I state that what is not there is what links the stones and bricks of a house. If it is mortar, it is a kind of glue that ties the stones together, if there is no mortar, it are the written and unwritten laws of an invisible gravity. Taking the metaphor[1] to organization studies, I chose to deal with the unwritten organizational laws of gravity by looking at what links the organizational building blocks (like organization behavior, structure, decision making, strategy etc.). I found a way of combining the objective of doctoral research with the desire to become a mason. The key was to focus on the mortar instead of on the bricks, on the spaces between the stones instead of on the stones themselves, on a language that uses a plethora of underspecified formulations as a vehicle through which I could work on difficult conceptual problems (Levine in Orton & Weick, 1990, p. 204). The set of constructs I have used throughout my research – High Reliability Theory (HRT) and SenseMaking (SeMa) – are a reflection thereof. I cordially invite you to be my guest on my journey into '*making sense*' of what I have read, observed and written, and to read this dissertation. I hope you will enjoy reading it as much as I have enjoyed writing it.

Also from another perspective, writing a thesis is like building a house. When you start you have a vague idea of what kind of building you want to construct, a house that fulfills your dreams, uttered or unuttered. The new to build house holds a promise of a new life and of the excitement and learning on the journey on your way to construction. Writing a doctoral dissertation shows more than one characteristic of such a construction project. Once one decides to go on this journey the dreams at times get very real, at other times however they seem to vanish with every step you take in achieving it. Then you ask people, especially friends who are going or have been going the same doctoral journey. They tell you their experiences and what they have gone through: The solitude, the struggle with theory, method and data, the reward in the end. You nod your head but still think that your own thesis will be different from all the others. In the end, you is still you. You still hold on to a romantic view of the academic in search of *Truth*. And then complete disappointment overcomes you and good friends really have to pull you through. The thing about PhD theses is that you come across yourself in the process. You get to know your strengths and weaknesses, start to see where the dangers and opportunities could be. These insights come at a cost however. You learn it the hard way, there is no easy way. *A PhD title is the proof of concept and the concept is you* (David Mendonça).

Writing an interdisciplinary thesis alone, is a contradiction in terms. I am not even able to pretend that this piece of work was a solo-activity. The scientific mores, however, require that I am the one and only author of the dissertation. However, I will use the plural 'we' throughout this thesis to indicate that most of the inspiration and creativity arose out of teamwork and that all thoughts and ideas presented in this thesis have been thoroughly improved through discussion with colleagues.

Needless to say, there are many people who have contributed to the completion of this thesis, in one way or another, as friends, colleagues, inspirers, critics, financers and advisors. First of all, I want to thank Bartel Van de Walle for being my thesis supervisor. He has been my guide in the doctoral process. He learned me how to set up good research, and thought me the true meaning of academic rigor. Above all he was a source of continuous inspiration and challenge. I thank him for the infinite number of hours he spent with me at the university, on the road, on the phone or Skype, on the research sites, on conferences etcetera. I especially am grateful for the way he welcomed me in his personal life. Without his energy and commitment I would not have completed this dissertation. It is as much his work as it is mine.

Still at Tilburg University I want to thank Piet Ribbers for his efforts and support for improving my thinking intellectually and his emphasis on keeping the academic line pure. Also for taking up the role of promoter of my thesis.

I am grateful to Willem Muhren and Raphaël Smals from Tilburg University for being my *companions de route* at the Bank and the NPP respectively. My thanks you go to Willem for his generosity in everything: the practical assistance, his sparring-partnership in the discussion of our research lines, the gratifying co-research in Sri Lanka, Congo and Finland, our joint papers and conference participations. Likewise, my sincere gratitude goes to Raphaël for the way he has helped my thinking – our thinking – on high reliability crystallize and for all his efforts in conducting my field research. I am indebted to Willem and Raphaël for their write-up of the incident processes in both our case studies.

I thank people at the former VLEKHO Business School, which has funded this thesis work. First and for all, I want to thank Dirk Van Lindt for taking me on board and for granting me the opportunity to start the doctoral research. It is his belief in me that paved the way for this dissertation. I also thank him for his kind assistance in analyzing my research data. Also thank you to Micheline Goossens, Karel Van Oostveldt and Wilfried Janssens, for their continuous belief in me. VLEKHO staff has gone to great lengths in supporting me financially, but I will especially remember them for the feeling of belonging they continuously gave me.

In addition, I am truly grateful for the time invested and interest shown by people at the two case sites. First, at the Bank, special thanks go to the general manager, who acted as a sponsor for my work and to Noël Van den Driessche, who profoundly believed in what we were doing and who hoped that the outcomes of our research would have the potential of improving his organization. At the Nuclear Power Plant I express thanks to Geert Backaert for the challenging conversations that went to the heart of how a Nuclear Plant really operates. Also for the trust he has put in me and for the unique and privileged opportunity he has granted me to be a first row witness of life at a nuclear power plant. I am grateful to Jacques Vanhuysse for explaining to me the ins and outs of the Maintenance & Repair Process and for facilitating my on-site observations and organizing the interview sessions. My appreciation goes to Franki De Prekel for his help with retrieving legacy data from the SAP database.

Down at NJIT, I have found great support in two people, Murray Turoff and Roxanne Hiltz: Murray, for being Murray, my oracle and role model as a scholar in heart and soul. The continuous sharing of his experience and the combing of his insights into practical relevance for my own research cannot be overestimated; Roxanne, for her help in choosing the right set of data analysis techniques and encouraging me with simple tricks like: "*every night, sit down at your desk, and just write it, damn'it*" (Although I am not sure she actually said "*damn'it*", but I'm pretty sure that's what she meant).

There are a number of colleagues that over the years have given me advice that might seem relatively insignificant at first sight but that have made a whole difference: David Mendonça, for challenging my scientific competencies; Noël Houthoofd, for making clear to me that it is no use to think ex-nihile about theories and fields of interest, without having the possibility to collect data; Dirk Kenis, for acquainting me with Bartel and for being the committed co-author of my first conference paper; Guido Pepermans, for making clear to me that in case of a PhD thesis 'good is

good enough'; Marc Craps, for the quality of his instructions in qualitative research; Hendrik Slabbinck for his help when data did not want to yield up their secrets so easily; Kristof Stouthuysen for the inspiring discussions on co-work; Koen Algoed for his encouragements and challenging discussions; Geert Crauwels, for his wisdom on life, in general, and that of a PhD candidate in particular.

Special thanks goes to my colleagues at Mechelen University College who have supported me during the last phase of the doctoral process. I am especially grateful for their understanding and patience when the combination of work and study was cumbersome. Still at Mechelen University College, my sincerest gratitude goes to Peter Berghmans who has been an eyewitness from the start and whose friendship is invaluable to me.

Last, but in fact first and foremost, my immense gratitude goes to my wife Els and our children, Kerlijne and Hendrik. The hours I have spent physically at my computer and the hours that I was absentminded and absorbed by research have deprived them from the quality time together they were entitled to. It is their generous effort that has permitted me to succeed. Therefore I dedicate this manuscript to them. Yes, I'm finally done.

Gerd Van Den Eede
November 2009

Chapter 1 Introduction

The more we study the major problems of our time
the more we come to realize
that they cannot be understood in isolation.
They are systemic problems, which means
that they are interconnected and interdependent
Capra (1996)

1 Introduction

The study of reliability is of considerable importance to society, and this from different perspectives. Society and mankind seem to be devoted to risky ventures. Throughout its evolution mankind has made progress by following a mixed strategy of risk averse and risk prone behavior, of sticking to the known values on the one hand and of searching for the unknown and the experiment on the other. This strategy has proved to be very rewarding considering the 'success' of our species. Many doubt this success from a socio-philosophical perspective, but contemporary life unarguably is much more safe and satisfying than life of previous generations. New technologies, new procedures, new places have been developed or discovered resulting in more welfare and (sometimes) more wellbeing. Hence it pays off to take risk, at least if the upside risk is greater than the downside risk.

With our apologies to Bob Dylan for stealing his title and to our readers for laboring an obvious point, but in a doctoral dissertation on reliability, we have no choice but to state it: The times, they are a-changin'. "*To succeed, organizations must now contend with complex global markets, large-scale systems, and a hyper-dynamic economic context, all of which require organizational members to detect and manage unexpected events in a rapidly changing environment* (Knight, 2004, p. 1). From a business perspective, reliability has shifted from the background to the focus of interest in recent years. Internationally, the awareness of operational risk management has increased tremendously[2]. Recent scandals stress the importance of operational reliability. Legal or regulating frameworks like Basel II and Sarbanes-Oxley (on operational risk), Code Lippens in Belgium and Code Tabaksblat in The Netherlands (on Corporate Governance) are streamlining ethical management practice and offer benchmarks to do so.

Anno 2009 organization members want to be taken seriously, want to be part of the decision making, want premium information on the organization and to foster their autonomy. The paradigms of the nineties on becoming a learning organization, to name just this management creed, should be seen in this light. However, there occasionally seems to be a discrepancy between what managers preach and what they do. They preach openness and say they believe in empowering their people, but in practice they want to keep control on everything and everybody. This should not come as a surprise since one of the most compelling shifts of the last decade has been the aforementioned need of being compliant.

With this dissertation we wish to make a contribution to the expertise developed by organization scientists in recent years in the field of highly complex and tightly coupled organizations (Roberts, Stout, & Halpern, 1994, p. 614). More particularly we hope to make clear in which way High Reliability thinking can find the balance between the desire to be open and the need to be in control, to exhibit a reliability that consists out of stability and flexibility. This study aims at contributing to the debate on what constitutes organizational effectiveness and in this sense it modestly subscribes to a long tradition that started with Adam Smith's *Wealth of Nations* (1776) and Frederick Taylor's *Principles of Scientific Management* (1911). Contrary to the mainstream organizational effectiveness research, the focus is not on efficiency (in the sense of 'doing the things right'), but on effectiveness ('doing the right things') and in this it fundamentally differs from seminal publications like Peters' and Waterman's *In Search of Excellence* (1982). However, this does not imply that the efficiency notion remains out of scope, since efficiency will prove to be indispensable in understanding effectiveness. The purpose of this research is to develop a theory that explains how organizational reliability can be enhanced by balancing structural and contextual organization factors. The title of this dissertation does not imply that we are going to *find* some kind of magic spell for assuring reliability, but that we are searching for insights into what constitutes organizational reliability. Insight itself does not increase predictability or reliability of complex systems, but it may give those trying to manage such systems indications where and how to look for clues to remain on course within the parameters of effectiveness and efficiency (Longstaff, 2003, p. 30). Based on our a priori deduction from the literature and our field observations, we argue that contextual dimensions, such as the degree of mindfulness and the way decisions are made, and structural dimensions, such as the overall focus/implicit strategy on efficiency and the way the Information Systems are used, have the potential of explaining (un)reliability.

This first chapter introduces the foundations our research is built upon: the whole of context, axioms, choices, problem definition, limitations that underlies the search we have embarked on. In line with Linstone and Turoff, we believe this is essential when building a framework that has the potential of contributing to the body of scientific research: "*Any human endeavor which seeks recognition as a professional or scientific activity must clearly define the axioms upon which it rests. The foundation of a discipline, as the foundations of a house, serves as a guide and basis for the placement of the building blocks of knowledge gathered through research and development activities. It is the definition, exposure, and investigation of the philosophical foundation that distinguishes a scientific profession from other endeavors*"(Linstone & Turoff, 1975, p. 15). […] "*Have we taken a broad enough perspective of the basic problem? Have we from the very beginning asked the right question? Have we focused on the right objectives*? […] (Linstone & Turoff, 1975, p. 19). In view of this objective, the remainder of this chapter first builds a phenomenological taxonomy of reliability, providing a definition of the reliability concept (Section 2). Next, the principle of triangulation introduces the multidisciplinary, system theoretic and paradoxical nature of our research (Section 3). Subsequently, the chapter addresses the notions of complexity (Section 4) and coupling (Section 5) as they are at the heart of what constitutes organizational reliability. Finally, the research questions are formulated (Section 6) and the structure of the dissertation presented (Section 7).

2 A Phenomenological Taxonomy of Reliability

Reliability is fragile, not only in its physical manifestation, but also as a construct. Yet one talks about reliability as if one perfectly knows what it means and that we all share the same mental model. Nothing is further from the truth. Depending on the discipline, the context and the individual or collective world-view of the person interpreting the term, the meaning of reliability is fundamentally different[3].

In this section we give an overview of the ways in which practice and academia deal with the concept and we make a beginning of what could qualify as a more generic phenomenological taxonomy of reliability, independent from the practitioner domain or scientific discipline. First, we give an overview of popular definitions of reliability, with an indication of their strengths and weaknesses and how they can be used in building the intended taxonomy. Next, we decompose the notion into its constituting parts and make the distinction between the domains in which concepts of reliability over the years are – or have been – applied (e.g. machine- or software-reliability). Third, we combine these insights by asking whether reliability is a matter of 'and/and' or of 'and/or'. Finding this answer is this dissertation's leitmotiv.

2.1 Defining reliability

Reliability can be defined in numerous ways, and the following is just a selection out of many possible definitions. But two threads seem to emerge from literature and practice: (1) Average reliability and (2) Variance of reliability. First, we look into how these two approaches get operationalized. After that, we present the definition of reliability we adhere to in this dissertation.

2.1.1 Average reliability

The first thing that comes to mind when thinking of reliability is that the object or process (tool, system, organization…) should be effective 'most of the time', meaning that we implicitly think in terms of averages. Often one can accept that something is not working, but it must work most of the time. The following is a selection of different notions of average reliability (or the probability thereof) in literature:

- "[*W]hat one can count upon not to fail in doing what is expected*" (Weick & Sutcliffe, 2001, p. 91).
- "*System effectiveness is the probability that the system can successfully meet an operational demand within a given time when operated under specified conditions*" (Prasad et al., 2001, p. 6).
- "[*T]he probability that a system will perform satisfactorily for at least a given period of time when used under stated conditions*"(Prasad et al., 2001, p. 2).
- "*System reliability is a measure of how well a system meets its design objective and it is usually expressed in terms of the reliabilities of the subsystems or components*" (Prasad et al., 2001, p. 2).
- "*The probability of performing a specified function without failure under given conditions for a specified period of time*" (Arblaster, Griffith, Hochmuth, Howells, & Reeves, 2005, p. 28).

2.1.2 Variance of reliability

Another characteristic of reliability is its spread. Here we make a distinction between the total time an object or process is reliable on the one hand, and the time spans between periods of reliability and unreliability and the duration of this unreliability on the other hand. The following is a sample indicating how this notion of variance of reliability is dealt with in literature:

- The unusual capacity to produce collective outcomes of a certain minimum quality repeatedly (Hannan & Freeman, 1984, p. 153): "*In a world of uncertainty, potential members, investors, and clients may value reliability of reliability more than efficiency. That is, rational actors may be willing to pay a high price for the certainty that a given product or service of a certain minimum quality will be available when it is needed. Reliability depends on the variance of reliability (including its timeliness) rather than its average level. Organizations have higher levels of reliability than ad hoc collectives in two senses: one cross-sectional and the other temporal. Cross-sectional reliability means that an outcome chosen at random from a population of organizations will have a lower variance than one chosen at random from a population of other kinds of producers. Temporal reliability means the variability over time in the quality (including timing of delivery) of an outcome is lower for those produced by organizations than for those produced by ad hoc groups. Overall, we argue that the distinctive competence of organizations is the capacity to generate collective actions with relatively small variance in quality*".
- "*[T]he lack of unwanted, unanticipated, and unexplainable variance in reliability*" (Hollnagel 1993, p. 51, Cited in Weick, Sutcliffe, & Obstfeld, 1999, p. 86).
- "*Performing reliability, maintainability and availability assessments of equipment, machines, subsystems and system, reliability being the probability that an item will perform a required function under stated conditions for a stated period; for example, how often a failure may occur, the estimated mean time between failures, the mean repair times and the availability and effectiveness factors*" (Azadeh, 2000, p. 209).
- For a computer engineer, IS reliability might stand for a *small* 'mean time between failure', or an *acceptable* 'mean time to repair', or an agreed upon Failure unit (FIT).[4]

The aggregation of average reliability and spread in reliability is called availability. Availability enables users who need to access information to do so without interference or obstruction, and to receive it in the required format (Whitman & Mattord, 2008, p. 9). Availability does not mean that information is automatically accessible to any user, but it needs verification of the user to become reachable to that nominated user. Purposefulness is built in the term 'availability' – it has connotations about benefit, relevancy, understanding, meaningfulness, effectiveness, and immediate usability (Kuusisto, 2006, p. 2). A widely accepted equation for availability (Fox & Patterson, 2002) is: Availability=MTTF/(MTTF+MTTR), where MTTF is the mean time to failure of a system or subsystem (i.e. the reciprocal of reliability), MTTR is its mean time to recovery, and Availability is a number between 0 and 1. The equation suggests that to improve availability, a 10x decrease in MTTR (for example) is just as valuable as a 10x increase in MTTF.

2.1.3 Our definition

So what determines these components of reliability? As can be derived from our discussion above, the element time plays a central role. Note also that reliability is not value-free and also that its meaning depends very much on the context. The complexity of finding a good definition of reliability is best captured by Rochlin: "*The criteria for and evaluation of reliability, whether defined positively by the dynamic of organizational structure and culture or negatively as the avoidance of seemingly inevitable errors and failures, are even more demanding than the traditional search for definitions and models of organizational effectiveness. Seen in this light, the problem of arriving at a consensual definition becomes a primary research issue rather than a disciplinary side-alley*" (Rochlin, 1993, p. 30).

For the purpose of our research we integrate the various components of reliability into the following generic definition of reliability:

> *Reliability is the system outcome that can be described as safe, effective and efficient, in terms of average and variance.*

It is the starting point for the decomposition that follows.

2.2 Reliability decomposed

We approach the reliability notion from its relationship to adjacent notions: Safety (2.2.1) and Performance, which in its turn can be decomposed as Effectiveness (2.2.2) and Efficiency (2.2.3). We posit that all these notions are subsets of reliability, as can be derived from Figure 1.1.

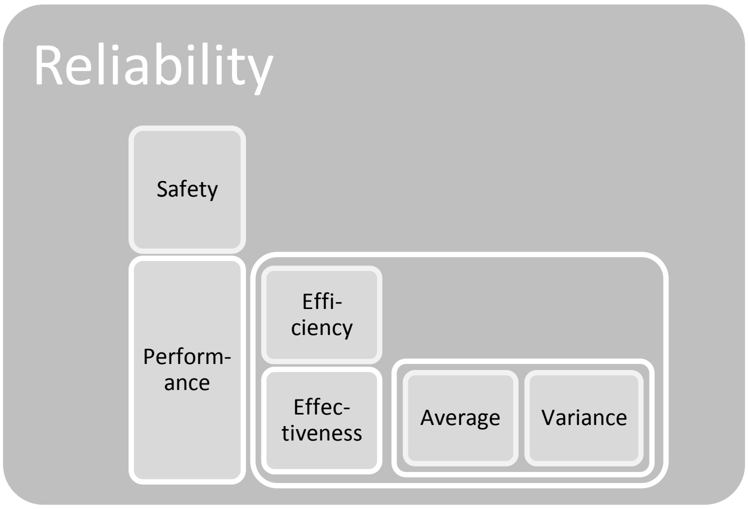

Figure 1.1 - Reliability decomposed

In what follows, we deal with these concepts in more detail, limiting ourselves to those aspects that are relevant to our research. First, we examine what can be learned from the study on safety in view of overall organizational reliability. Next, we argue in what way insights from engineering can contribute to organizational effectiveness. Finally, our focus is on the efficiency paradigm, and more, in particular on the inherent tension with effectiveness.

2.2.1 Safety

A great deal of reliability literature is on safety, not reliability. There is an intuitive link between both notions, so the study of safety in this sector can contribute to what we know on reliability in a broader sense. In order to do so, the precise nature of safety needs to be explained first. We do so by drawing mainly on findings from the nuclear energy sector, but first we provide a framework regarding safe and unsafe industries. In view of their potential contribution to the understanding of reliability, we look at the difference between incidents, accidents and crises.

Incidents and accidents

Scholars[5] in the field of reliability studies and safety all have their own interpretation of the terms *incident*, *accident* and *crisis*. Perrow, for example, has proposed a taxonomy of incidents and accidents, and to understand his conclusions it is important to know what he means by an accident, and what he does not mean by it (1999, p. 65-66). A comparative analysis of these terms, may allow us to gain insight in the mechanisms they originate from. Perrow defines incident as a failure involving damage that is limited to parts or a unit, whether the failure disrupts the system or not, meaning that the output ceases or decreases to the extent that prompt repairs are be required (Perrow, 1999, p. 66). An accident is defined by Perrow as "*an event that is unintended, unfortunate, damages people or objects, affects the functioning of the system of interest, and is non-trivial*" (Perrow, 1999). There are two types of accidents: component failure accidents, which "*involve one or more component failures (part, unit, or subsystem) that are linked in an anticipated sequence*" and 'normal accidents,' or system accidents (Perrow, 1994). Normal accidents encompass multiple component failure accidents, and they are 'normal' because we expect that they will occur at some time in complex systems. Perrow (1994) explains: "*Two or more failures, none of them devastating in themselves in isolation, come together in unexpected ways and defeat the safety devices [of a system] – [that is] the definition of a 'normal accident' or system accident*".

Crises

Pearson and Clair (Pearson & Clair, 1998) provide the following definition of crisis: a low-probability, high impact event that threatens the viability of the organization and is characterized by ambiguity of cause, effect, and means of resolution, as well as by a belief that decisions must be made swiftly. This leads to the following characteristics:

- highly ambiguous situations where causes and effects are unknown
- a low probability of occurring but posing a major threat to the survival of an organization.
- little time to respond
- surprise organizational members
- dilemma in need of decision or judgment that will result in change for better or worse.

Further Pearson and Clair (1998, p. 64) mention that all crises share the following characteristics:

- a breakdown in the social construction of reality;
- organizational leadership which is likely to come under close scrutiny. Turnover of (or revolt against) leadership may be likely as well;
- organizational members are likely to question the organization's cultural beliefs and to feel a need for a transformation of the culture;
- crisis management is unlikely to be successful without a reformation of organizational leadership and culture.

Human factor

It has been reported upon in many disciplines that a compelling number of causes of accidents and incidents can be attributed to human action so that there is a wide-spread consensus that human error plays an important role in unreliability (Reason, 1990;1997). Bea and Moore (1993) and Roberts and Bea (2001a) report up to 80% of maritime accidents finding their root in human failure. Azadeh (2000) argues the same for security failures in organizations but also shows that the technical failure should not be minimized either. Recent research on the Chernobyl nuclear disaster (Salge & Milling, 2006, p. 89) has pointed out that this accident was caused by the combination of human failures in the design of the reactor and on-line operations[6]. As such, this suggests that a pure univocal emphasis on either human error (e.g. Dörner, 1996) or technical or 'system' failure (e.g. Perrow, 1999) cannot offer valuable insights.

Safe and unsafe industries

Amalberti et al. (2005) provide a framework (shown in Figure 1.2) for categorizing the risk of catastrophic events across industries. They posit that the safe and unsafe industries differ greatly since some sectors continue to have a low safety level (for example, transport by micro-light aircraft or helicopter, and emergency surgery), some are stuck at an average safety level (for example, road safety and occupational accidents in trade or fishing), some are at good levels (for example, the petrochemical industry and anesthesiology), and the best have achieved safety levels beyond 10^{-6} (for example, the nuclear power and civil aviation industries).

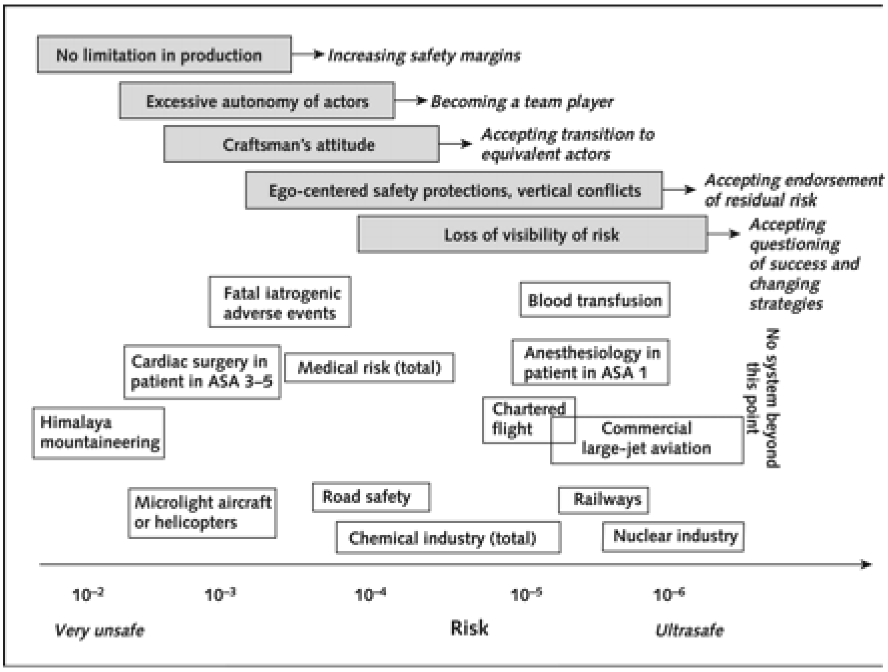

Figure 1.2 - Average rate per exposure of catastrophes and associated deaths in various industries and human activities (Amalberti, Auroy, Berwick, & Barach, 2005, p. 758 - Reproduced with permission from the Annals of Internal Medicine)

The convergence of safety and reliability in the nuclear energy sector

The nuclear energy sector, in recent years, has come to pay considerable attention to the notions 'safety' and 'safety culture' (IAEA, 2002a;IAEA, 2002b). This is a particularly interesting phenomenon as in the nuclear context safety and reliability seem to converge to a great extent.

Indeed, if the nuclear installation is performant it is also considered to be safe and, vice versa, in order to be safe it has to be performant. Fucks (2004) puts it as follows: "*Reliability is different from nuclear safety because it indicates the quality of a device or equipment to function as intended. Reliability is, for some part of the system or for the system as a whole, the probability of non-failure*".[7] In this she clearly makes the distinction between reliability (*fiabilité*) and safety (sûreté). Nevertheless, especially in the field of nuclear energy production, both notions are interrelated: human safety cannot be seen independent from reliability. In the same way as in the case of mainstream organizations where operational reliability did not emerge suddenly, also in the nuclear sector the topic of nuclear safety went through some phases before it got shaped as we know it today. Fucks (2004, p. 24-25) distinguishes three major phases during which quite an evolution took place from an engineering approach in the 1970s, over a technical approach of human error in the 1980s, towards a human factor approach 1990s that valorizes the existence and influence of a safety culture and the organizational factor. What started in the nineties of the last century as an emphasis on the 'organizational accident' (Reason, 1997) is reinforced at the beginning of this decennium by adding yet another dimension, that of a set of mind oriented towards safety that goes beyond technical, procedural or managerial aspects of safety (Fucks, 2004, p. 25).

2.2.2 Effectiveness

Lessons from engineering

We adhere to a quite straightforward definition of effectiveness: Something that is effective works well and produces the results that were intended. In this dissertation we focus on the non-technical aspects of effectiveness. We are therefore unconcerned with machine reliability (e.g. in terms of technical redundancy) but rather are interested in aspects of reliability resulting from procedure, culture, organization design, human resources management, co-ordination mechanisms, etc. Nevertheless, we can learn from the reliability engineering principles for our purpose because it is a much older discipline than organizational reliability and offers valuable and tested jargon and insights. The primary goals of reliability are the following (Prasad et al., 2001, p. 1):

1. Keeping the system as simple as is compatible with the reliability requirements;
2. Increasing the reliability of the components of the system;
3. Using parallel redundancy for the less reliable components;
4. Using standby redundancy which is switched to active components when failure occurs;
5. Using repair maintenance where failure components are replaced, but not immediately switched in, as in (4);
6. Using preventive maintenance such that components are replaced by new ones whenever they fail, or at some fixed interval, whichever comes first;
7. Using better arrangement for exchangeable components;
8. Using large safety factors or product improvement management program; and
9. Selecting burn-in components that have high infant-mortality.

Noteworthy is that Prasad and colleagues (2001, p. 1) argue that the implementation of the above steps to improve system reliability will normally consume resources. A balance between system reliability and resource consumption is essential.

The above deals with the reliability of a 'system'. A system can be characterized as a group of stages or subsystems integrated to perform one or more specified operational functions (Prasad et al., 2001). A 'part' or 'element' is the least subdivision of a system or an item that cannot ordinarily be disassembled without being destroyed. A 'component' is a collection of parts which represent a self-contained element of complete operating system. 'Unit' and 'component' are synonymous; They are assembled to form a 'stage' or 'subsystem' (Prasad et al., 2001, p. 2).

In describing the reliability of a given system, it is necessary to specify:

- the equipment failure process;
- the system configuration which describes how the equipment is connected and the rules of operation;
- the state in which the system is defined to be failed.

The equipment failure process describes the probability law governing these failures. The system configuration, on the other hand, defines the manner in which the system-reliability function will behave. The third consideration in developing reliability function for a non-maintained system is to define the conditions of a system failure (Prasad et al., 2001, p. 2).

Lessons from organization theory

Since Taylor and his Scientific Management till today, the topic of organizational effectiveness has got a lot of attention. Especially the relation between effectiveness and efficiency has driven research for many years. The general observation in this respect is that, although the best performing organizations are both effective and efficient (Katz & Kahn, 1978), there may be trade-offs between the two. Thus, an organization can be effective, efficient, both, or neither (Ostroff & Schmitt, 1993).

With the publication of popular books such as Peters' and Waterman's *In Search of Excellence* (1982), excellence (quality, continuous improvement, transformation, revitalization and so on) was brought to the forefront. This quality focus has dominated management research and practice until the beginning of the new millennium. Then the tone changed from an efficiency focus to one that fosters effectiveness. The new creed became managing (operational) risk, with much less focus on efficiency as a result. The problem with this literature is captured by Roberts: "*To the extent that the organizational literature deals with reliability at all, it deals with effectiveness. However, the effectiveness literature deals with a whole range of outcomes, none of which are reliability*" (Roberts, 1990a, p. 103). Such a decomposition shows reliability is about flexibility because a system that is perfect in repeating what it has done successfully in the past has no guarantee that it will be able to deal with unpredictability, i.e., future events for which there is no link with the past or the present (Weick et al., 1999, p. 86).

Because of this shift from efficiency towards reliability scholars began to investigate non-normal organizational reliability situations from the mid eighties onwards (Whetten & Cameron, 1994), including high reliability systems.

The combination of these two trends (i.e. a focus on effectiveness and the study of non-normal organizational reliability) forms the basis for the research on organizational effectiveness in this dissertation.

2.2.3 Efficiency

Whereas effectiveness refers to an absolute level of either input acquisition or outcome attainment, efficiency refers to an input-output ratio or comparison (Ostroff & Schmitt, 1993, p. 1345). This description of both notions ignores the complex and paradoxical nature of the relation between them. In this subsection, we tackle the duality that exists between them. To this end we introduce efficiency-related concepts that are necessary for our line of reasoning.

Slack

It is assumed that organizational slack, in terms of time and human resources is important for organizations coping with the challenges of the 21st century (Lawson, 2001). Increasingly complex systems and technologies require more, not less, time for monitoring and processing information. Flexibility and adaptation, creativity and innovation only exist when the organization allows for sufficient slack in its processes. However, this is more easily said than done since slack is often sacrificed on the altar of short-term efficiency. Even though there seems to be a consensus that driving slack out of the processes is of no avail to long-term effectiveness and that it is recommended that not all resources be committed to immediate output efforts, it is the imperative of being profitable in the short run that is the main driver for organizing.

For these reasons, any balance between effectiveness and efficiency is doomed to be brittle. Our claim is that organizations capable of dealing with this fragility consistently, can be called high reliability organizations.

Efficiency favors effectiveness

The general belief concerning the duality between effectiveness and efficiency holds that an orientation towards effectiveness is a better determinant for organizational reliability than an orientation towards efficiency (Lewin & Minton, 1986). However, following Ostroff and Schmitt (1993), we hypothesize the opposite. In their study on school effectiveness and efficiency they found support for the importance of a high level of cost consciousness. The acknowledgement of this paradox is the basic thread running through the organizational choice model on competing values (Quinn & Rohrbaugh, 1983). With this study we want to continue this line of research. The question that comes to mind in this respect is whether reliability is a matter of adding measures on top of each other or is it a matter of choosing measures to implement on the one hand, and eliminating some other measures on the other hand? In other words: is it an additive model[8] or a 'replacement' model?[9] The risk persists that one source of unreliability is replaced by another source of unreliability.

Whereas 'Excellence' (Peters & Waterman, 1982) was the management creed of the eighties and nineties of the previous century, the paradigm of this decade seems to have shifted towards 'Reliability'. The reliability paradigm shows itself through an emphasis on operational risk management in the aftermath of the Barings, Enron, WorldCom, Parmalat or Société Générale failures, to name just these. The question that can be heard in boardrooms is: '*Can we be certain that our systems – in the broadest sense – will be sufficiently functional to guarantee business continuity?*' And also: '*What measures do we have in place to guarantee a sufficient recovery?*' This change is quite remarkable because also in business, until recently, reliability was not an issue. There simply was no reason to take notice of it: business environments were more stable and less complex than they are today and a compelling regulation, forcing the organization to put the reliability issue on the board table, was lacking. Besides, over the years the idea had emerged that systems are safe and reliable. Indeed, most systems have a very impressive reliability track record. Therefore, when thinking about reliability, the null hypothesis is that a system is reliable and, because failure is the test criterion used, we can never accept that hypothesis simply because we have failed to reject it over some given period of time (Wolf & Berniker, 2008).

Therefore it is no wonder that reliability – although considered an organization's bottom line – has not revealed all its secrets in full yet. We can assume there still are some 'dark sides' that need enlightenment, even sides we have not even started to realize they exist. With this study we wish to address this dark side of reliability and while full comprehension is unlikely, but that nevertheless some relevant progress can be made by changing perspectives.

2.3 Methods for evaluating reliability

2.3.1 Cartesian reductionism – Risk equation

Since the Renaissance, and until the beginning of the previous century, scientist were guided by a strong Cartesian belief that if a system could be reduced to its basic forces and one could compute how those forces interacted, one could predict anything (Longstaff, 2003, p. 11). The study of reliability and risk would be reduced to an equation, its management to checklists, analysis and evaluation. The method of the risk equation is the most straightforward and most frequently used: "*Risk is the uncertainty inherent in doing business; technically, it is the probability associated with losses (or failure) of a system multiplied by the dollar loss if the risk is realized*" (Straub & Welke, 1998, p. 442).

This method has the appealing advantage that it is straightforward to understand, and – at least at first sight – easy to implement and follow-up. This simplicity is deceiving, however, as has been pointed out by several researchers. Baskerville, for instance, argues that even such simple arithmetic becomes exceedingly complex because of "*the interwoven nature of the wide variety of threats, the vast array of safeguards, and the variance of levels of probability and loss that are unique to every organization*" (Baskerville, 2005, p. 6). He continues: "*Threats and safeguards are overlapping. As a consequence, a database of threats, probabilities, potential losses, and potential safeguards can be complex*" (Baskerville, 2005, p. 6).

Since modern times, we have learned a lot and in the post-modern era we live in, we have come to realize that there is no such thing as a reliability or risk equation, much as this is desirable. Nonetheless, some of the most important methods of assessing and evaluating risk and reliability – for an overview of some of the methods, see Table 1.1 – seem to swear by the old adagio of reductionism, be it with the necessary annotations or even self-criticism.

Preliminary Hazard Analysis (PHA)
Computer Simulation of system behavior
Monte Carlo failure simulation
Event Tree Analysis (ETA)
Fault Tree Analysis (FTA)
Human Reliability Modeling and Analysis
Hazard and Operability Analysis
Time continuum failure modeling and analysis
Failure Modes and Effects Analysis (FMEA)

Table 1.1 - Overview of some reductionist risk management methods (Azadeh, 2000, p. 208)

2.3.2 Reasonian holism

An alternative for the Cartesian approach is to focus on the composition of this 'reliability cocktail'. There seems to be a need for holistic studies that underpin how aspects of organizational design and task environment interact to affect organizational reliability (Pearson & Mitroff, 1993;Lin & Carley, 2001).

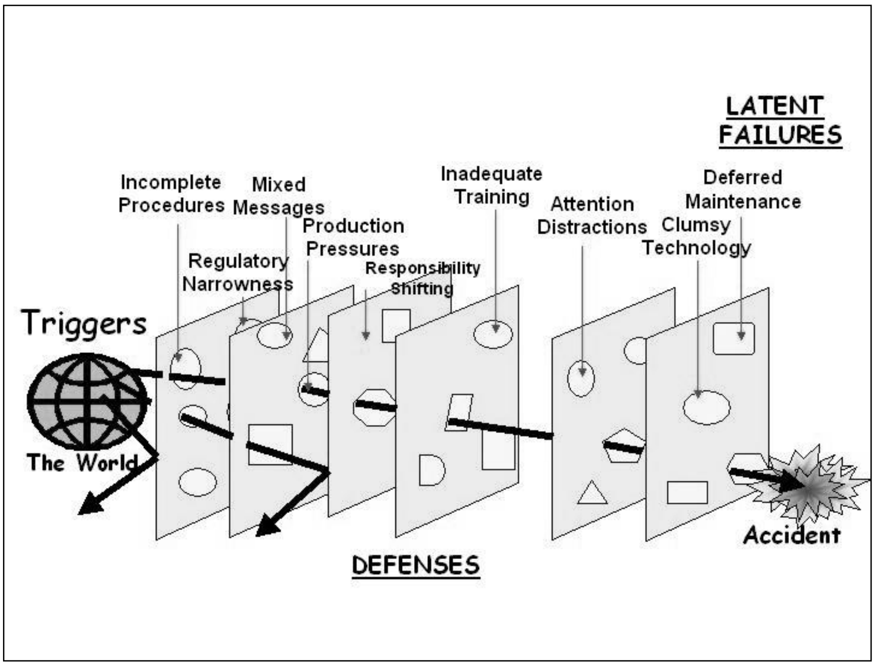

Figure 1.3 - Swiss Cheese Model (Modified from Reason, 1990, p. 208)

A first approximation to this holistic view on reliability is the Swiss Cheese metaphor, developed by Reason (1990). An organization is exposed to all kinds of threats from various internal and external sources. The organization may protect itself from these threats, but threats can still cause an organizational accident, as depicted in Figure 1.

Reason argues that each of the levels present in Figure 1.3 forms a layer that can prevent inputs of a malicious nature ('threats') from propagating through the entire system. Each layer forms a line of defense against specific types of threats. Because of the obvious analogy, this model of perforated layers, or slices, is referred to as the 'Swiss Cheese Model' (Reason, 1990;Reason, 1997). Defenses, barriers, and safeguards occupy a key position in the system approach. High technology systems have many defensive layers: some are engineered (alarms, physical barriers, automatic shutdowns), others rely on people (surgeons, anesthetists, pilots, control room operators), and others depend on procedures and administrative controls. For the purpose of our research, the Swiss Cheese Model, we formulate three remarks.

First, in an ideal system, each defensive layer would be intact or should have a limited number of 'holes'. Together, they should form a defense system that prevents threats of any kind to effectuate in the system. However, in practice, in each of the layers in Figure 1.3 holes do exist, allowing some threats to pass through a line of defense. Although a single threat crossing one of the defenses may not directly result in disaster, such a threat can trigger another event or risk, which may in the worst-case slip through the next line of defense, depending on where exactly the gaps in the layers are.

Second, an additional problem is that – unlike in the Swiss cheese – the holes are continually opening, shutting, and shifting their location. This is due to changes in the organization that are bound to occur continuously as the organization develops and changes over time, the gaps in the subsequent layers will be dynamic[10]. The consequence is that eventually, at one point in time, the holes will line up, allowing a threat to escalate throughout the various layers of the organization. The result is an organizational accident: a latent danger becoming manifest as it bypasses all built-in defense mechanisms, routing its way through the holes in the system.

Third, because of the dynamic nature of organizing, when one hole is plugged, another one may emerge elsewhere. Traditional risk management in such a setting is of not much use: finding the holes in the cheese (risk identification), estimating their importance in terms of impact and frequency (risk assessment), and finally, plugging them by effectuating the appropriate response (risk mitigation). The mainstream risk frameworks and best-practices, evangelized by consultants and business schools alike, propagate this same approach as sanctifying. We posit that guaranteeing tomorrow's reliability by managing today's risks is at best a partial solution for the foreseeable problems, but at worst, tells nothing about the future reliability in terms of the management of the unforeseeable ones.

Fourth, as important as the holistic view offered by the systems thinking perspective, is the constructivist triangulation approach we adhere to (Berghmans, Van Den Eede, & Van de Walle, 2008). In our philosophical assumption of the ontological and epistemological character of reliability, risks cannot be treated as a physical attribute 'out there' that can be measured (Oscarson, 2007). Risk identification based on this worldview assumes risks to be mediated through social experience and interaction (Renn, 1998). This stems with a constructivist view, which – in contrast to the objectivist approach – sees risk as a social artifact, produced by social groups or institutions, and determined by structural forces in society (Oscarson, 2007).

From the above, one could derive that in a very complex environment, a univocal approach to risk and reliability is not what is needed. More than one mechanism, tool, backup, etc. is needed. The danger however is that too many mechanisms might interrelate in an unforeseen manner. This idea refers to the notion of redundancy where you also see a two-sided cutting sword. Redundancy is good, but too much redundancy is dangerous because the defense mechanisms might interrelate, hence endangering the complete system. Besides, the conventional practice of managers is to limit redundancy, to obtain the best possible fit to contextual conditions, and to maximize efficiency (Nohria & Gulati, 1996). This viewpoint is reflected in organization and economic theory. Transaction cost economists, for instance, consider redundancy synonymous with resource waste. Agency theorists go even one step further and think of redundancy as an opportunity for actors to pursue their own interests rather than act in the interest of the organization (Jensen, 1993).

On the other hand, it has been acknowledged that redundancy also has positive aspects. Cyert and March (1963), for example, proposed that organizations with slack find it easier to resolve goal conflicts between political coalitions, because redundant structures offer alternative options. They distinguish between three types of redundancy: (1) Information redundancy, (2) Task redundancy and (3) Relation redundancy. Information redundancy could be defined as the amount of unutilized possibilities to carry information. Once more, also this type of redundancy has an upside and downside component. Carley (1990), for instance, pointed out that increasing information redundancy may not only be a stimulus for (organizational) learning, leading to an increase in reliability, but that at the same time it might be detrimental to reliability because it adds to task complexity. As such, it is vital to find the balance between information redundancy and task complexity. A typical example is provided by Jervis (1997, p. 570): "*Adding redundant safety equipment makes some accidents less likely but increases the chances of others due to the operators greater confidence and the interaction effects among the devices*".

3 Triangulation

If we genuinely want to understand more about reliability, we believe we must do so (1) by relying on multiple disciplines, (2) by taking a systems thinking perspective, (3) by acknowledging and fostering paradox and (4) by looking beyond the boundary.

3.1 Multidisciplinary

A first road that can lead to understanding more about reliability is to study the implications of alternative organizational choices in detail and to assess their impact on behavior, as this behavior is known to shape overall organizational reliability (Bourrier, 2005, p. 100). The numerous recent examples of collapses of organizational reliability (supra) teach that risks are not homogenous by nature as they involve multiple aspects. Therefore, their management must be multidisciplinary as well. For this reason, we make use of organization theory (in particular organization design and organization behavior theory), economics, as well as information systems and integrate theory by looking through these lenses. It is generally accepted that dealing with a complex system involves a variety of disciplines (Azadeh, 2000, p. 210).

3.2 Systems thinking

A second guideline is that one must be alert to critical problems falling between disciplines. There is a need for an integrated method to identify gaps at interfaces and any overlooked weak points. Indeed, the danger lies in the system, not in the components (Azadeh, 2000, p. 206).

Hence, the gaps between the components are what should be the object of our study. Such calls for a holistic kind of thinking, also known as systems thinking (McLucas, 2003;Alter, 2004). Various approaches to organization studies are feasible, systems thinking being one of them, even though "*[systems thinking] can hardly be regarded as a new approach to scientific thought*" (Koontz, 1980, p. 180). For our own research, we take the way Scott Snook (2002) has managed to identify these gaps in his application of systems thinking. This is explained next.

In what follows we subsequently address the nature of systems, their boundaries and of thinking in an effort of finding out in what way they are valuable for understanding reliability.

Ludwig von Bertalanffy has described a system as "*an entity which maintains its existence through the mutual interaction of its parts*" (Bellinger, 2008b). Crucial in the concept of system is the fact that there is mutual interaction (cf. interactive complexity) which will over time lead to emergent behavior that again is inherently part of the system. This interconnectedness in combination with the time dimension will lead to characteristics that cannot be found as a characteristic of the system's individual components (Bellinger, 2008b). As a rule, people have inadequate understanding of systemic behavior (Sterman, 1989). This means that often they have no awareness for the drama that goes along with even a small failure or disruption. Presumably, it is beyond their cognitive, meta-cognitive and affective capabilities so that they notice too late what is really going on or that they make the wrong decisions to mitigate or compensate for what is happening. This interconnectedness is what distinguishes systems from non-systems.

In fact, systems thinking theorist Peter Senge advises against the bias of looking for problem causes in convenient places, to look beyond the system boundary (Moberg, 2001, p. 21): "*[There] is a fundamental characteristic of complex human systems: 'cause' and 'effect' are not close in time and space. By 'effects', I mean the obvious symptoms that indicate that there are problems ... By 'cause' I mean the interaction of the underlying system that is most responsible for generating the symptoms, and which, if recognized, could lead to changes producing lasting improvement. Why is this a problem? Because most of us assume they are—most of us assume, most of the time, that cause and effect are close in time and space*" (Senge, 1990, p. 63).

One such view is systems thinking. (Successful) Systems thinking is about being able to see the whole picture or context of a situation and its interconnections to its environment (Wolstenholme, 2003, p. 20). Such a perspective enables unintended consequences of well-intended actions to be pre-empted and minimized. Systems thinking reverses the three-stage order of Machine-Age thinking:

(1) decomposition of that which is to be explained;
(2) explanation of the behavior or properties of the parts taken separately, and;
(3) aggregating these explanations into an explanation of the whole.

Note that this third step corresponds to synthesis.

Opposed to the Machine-Age thinking, the systems approach has a different characterization, also three steps:
(1) Identify a containing whole (system) of which the thing to be explained is a part;

(2) Explain the behavior or properties of the containing whole and;
(3) Then explain the behavior or properties of the thing to be explained in terms of the role(s) or function(s) within its containing whole.

Note that in this sequence, synthesis precedes analysis.

In analytical thinking, the thing to be explained is treated as a whole to be taken apart. In synthetic thinking, the thing to be explained is treated as a part of a containing whole. The former reduces the focus of the investigator; the latter expands it. These two approaches should not (but often do) yield contradictory or conflicting results since they are complementary. Development of this complementarity is a major task of systems thinking. Analysis focuses on structure; it reveals how things work. Synthesis focuses on function; it reveals why things operate as they do.

The cure for this deeply rooted practice can be best described as systems thinking. It forms the backbone of this dissertation. Systems thinking suggests that when we understand the structure of a system, we are in a much better position to understand and predict the behavior of the individual elements (people) and their relationships and can therefore make better decisions. Everybody's consciousness is limited by space and time, which presumes that a human being is necessarily unable to know the world in its entirety. In this respect, systems thinking can serve as an antidote for prejudice. In what follows we describe Reasonian holism as a way to go beyond this innate limitation.

3.3 Paradox

The notions of opposites, contradictions, dialectics, tensions, dilemmas, and paradoxes constitute an important basis for social science theorizing (Das & Teng, 2000, p. 84). This should not come as a surprise since all organization is founded on paradox (Clegg, da Cunha, & Cunha, 2002, p. 483-484). On the one hand, an organization consists of independent human beings who freely commit to cooperate but on the other hand – in order to make this cooperation feasible – see their freedom bounded by rules and control. In essence, this is a paradox of centripetal (i.e. constraining) structure vs. centrifugal (i.e. enabling) structuring (Clegg et al., 2002). "*Routines, resource allocations, interpretive schemes and norms, are all examples of 'poles' that create structural constraint. Structuring will be centrifugal and enabling. It is agency and everyday practice that accomplishes structuring*". In our view, this last statement explains the persistence of this paradoxical situation. A *new deal* of organizing is needed to cope with an endless array of conflicting choices by creating an organizational culture with shared beliefs, values and competencies without encouraging a herd mentality and trampling on the uniqueness of individual personality and creativity (Thite, 2004, p. 139).

We believe such may be particularly true when studying a multifaceted reality like organizational reliability. So far, we have illustrated that reliability is paradoxical by nature. In order to be reliable, an organization has to be flexible and stable, efficient and effective, in the long run, but also in the short run, etc. In general terms, logical paradox can be defined as "*two contrary, or even contradictory, propositions to which we are led by apparently sound arguments*" (van Heigenoort 1967 cited by Poole & van de Ven, 1989, p.563). Typical of a paradox is that these opposites are clearly present and are generally accepted as worth striving for (Quinn &

Cameron, 1988). Acknowledging this paradox and trying to understand or manage it is a far better plan than trying to categorically choose for either of the two extremes. Indeed, such a choice would merely result in a pendulum swinging between the two extremes, leading to a tremendous loss of energy.

For this reason theory building has to "*move away from 'consistency' and towards 'the resolution of tensions or oppositions*'" (Poole & van de Ven, 1989, p. 563). Such an approach would mean the emergence of "*a dynamic theory that can handle both stability and change, that can consider the tensions and conflicts inherent in human systems*" (Quinn & Cameron, 1988, p. 27). Poole and van de Ven posit that theories are "*not statements of some ultimate 'truth' but rather are alternative cuts of a multifaceted reality*" (Poole & van de Ven, 1989, p. 563).

In this dissertation we follow Poole and van de Ven (1989, p. 562) in their methodology as they distinguish four different modes of working with paradoxes:

1. accept the paradox and use it constructively (Opposition)
2. clarify levels of analysis (Spatial Separation)
3. temporally separate the two levels (Temporal Separation)
4. introduce new terms to resolve the paradox (Synthesis)

"*A great deal can be learned from juxtaposing contradictory propositions and assumptions, even if they are incompatible. Theorists may feel a strain toward cognitive consistency, but that does not mean that theories must fit together neatly. Paradoxes remind theorists of this inconsistency and enable them to study the dialectic between opposing levels and forces which are captured in different theories*" (Poole & van de Ven, 1989, p. 566). By contrasting theories, constructs and concepts, we ask the questions that before were unuttered and attempt to make connections that before were unthinkable. We temporally separate the levels on which they are analyzed by making the distinction between (for instance) (1) individual vs. team vs. organization, (2) collaborator vs. executive and (3) physical proximity vs. physical distance. Researchers who take this approach must grapple with difficult and important theoretical problems. For instance: despite much research on the aggregation of individual acts, attitudes, and preferences into social actions, climates, and choices, these are still no completely satisfactory solution to the paradox (Poole & van de Ven, 1989, p. 566). Finally, a set of new terms is needed to resolve the paradox. "*The resolution of paradoxes by level distinctions or temporal analysis leaves each set of assumptions or processes basically intact. Both sides of the paradox are assumed fundamentally sound, and the paradox is resolved by separating them and specifying how one side influences the other. However, it is also possible that the paradox may stem from conceptual limitations or flaws in theory or assumptions. To overcome these limitations it is necessary to introduce new concepts or a new perspective*" (Poole & van de Ven, 1989, p. 567). "*However, such advances are hard-won, and many apparent resolutions may lead to dead ends. When perspectives radically shift, theorists may lose as well as gain. The new perspective may oversimplify some issues or ignore the problems that originally gave rise to previous positions. These risks are the price theorists pay for theoretical advances*" (Poole & van de Ven, 1989, p. 567).

Throughout our research, we combine these four strategies of dealing with paradox. As such we acknowledge the *Genius of the 'and'* (Graves & Waddock, 2000, p. 414) and oppose the Tyranny of the 'or'. In fact, the reconciliation between 'or' and 'and'-like thinking lies in the notion of ambiguity. Dealing with ambiguity is thinking in both the registers of 'and' and 'or'.

3.4 Triangulation: multidisciplinary, system theoretic and paradoxical

This dissertation makes a start in acknowledging paradox and does so by proposing a system theoretic perspective supported by a thorough triangulation of research theory and method. As for theory, we build on High Reliability Theory (HRT) and SenseMaking (SeMa), while we examine the role of Information Systems (IS) Fit. In the elaboration of this dissertation, we deal with these issues in more detail. They are covered in Chapter 2. For method, we rely on qualitative and quantitative data collection and analysis methods, the hermeneutic approach underlying our research is presented in chapter 3, leading to a reconceptualization of our theoretical framework in chapter 4. In chapter 5 the reconceptualized model is presented and the propositions and hypotheses developed. They are analyzed in chapter 6 and discussed in chapter 7.

3.4.1 Study unreliability as well as reliability

Management practice and literature tends to develop a bias towards the investigation of successful organizations, thereby neglecting the research of failures (Denrell, 2003). Failures as such are under-sampled which is dangerous because it is impossible to understand reliability if one does not understand *un*reliability. The consequences are important. For instance (Denrell, 2003, p. 228), the fact that only successes are looked into, will mistakenly show that risky behavior is rewarding in terms of reliability but this observation and conclusion does not take into account that risk-taking in many cases has led to failure because these cases are under-sampled. This might lead to a remarkable result in the sense that even if a practice is frequent among organizations with high reliability, it does not follow that the practice is linked to success. The most well-know example might very well be Peters' and Waterman's (1982) 'In Search of Excellence'. Like the drunken man who has lost his keys, the organization study discipline has a tendency to look where the light is (Clarke, 1993;Roberts & Bea, 2001b). Instead they should pay attention to a language that uses a plethora of underspecified formulations as a vehicle through which one could work on difficult conceptual problems (Levine, quoted in Orton & Weick, 1990, p. 204). One of the main conceptual problems is how to combine reliability and flexibility (c.q. effectiveness and efficiency; bureaucracy and adhocracy). These concepts are worth pursuing but difficult to realize simultaneously (Figure 1.4). This observation explains the almost continuous swinging of the pendulum between extremes such as centralization and decentralization, trust and control.

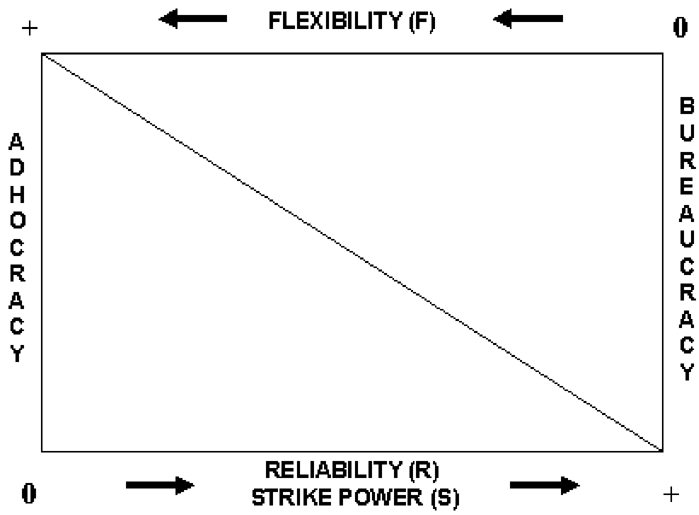

Figure 1.4 - Combining Reliability and Flexibility (Van Den Eede, Kenis, & Van de Walle, 2004)

As discussed above, if the purpose is to find out what constitutes reliability it cannot be found in any single element of the system. Hughes et al. after having investigated reliability in British air traffic control, expressed it as follows (Hughes, Randall, & Shapiro, 1992, p. 119): *"It is certainly not to be found in the equipment….for a period of several months during our field work it was failing regularly….Nor is it to be found in the rules and procedures, which are a resource for safe operation but which can never cover every circumstance and condition. Nor is it to be found in the personnel who, though very highly skilled, motivated and dedicated, are as prone as people everywhere to human error. Rather we believe it is to be found in the cooperative activities of controllers across the 'totality' of the system, and in particular in the way that it enforces the active engagement of controllers, chiefs, and assistants with the material they are using and with each other*".[11] Behavior that is asymmetric (cf. Snowden) from the symmetric behavior that could be expected when reading the procedures and organization charts. Although it is useful to have a clear understanding of every element within a system, from a systems perspective, this will not necessarily lead to a complete understanding of the whole system. This vision has some resemblance with an old Indian story about the blind men and the elephant. They all touched a different part of the animal. When they tried to describe what they felt, everyone gave a different description, which leads to an inconsistent total image of the animal (Aerts, 2008, p. 45).

We adhere to Weick's translation of Ashby's law of requisite variety – only complexity can cope with complexity – to the way organization studies should be conducted, namely to complicate yourself (Weick, 1995, p. 56). This becomes obvious in the conceptual models built, the combination of techniques that are used, and the underpinning theoretical frameworks. It becomes even more obvious in the use of constructs stemming from High Reliability Theory (HRT) or SenseMaking (SeMa). Such constructs have the potential of taking the discussion a bit further than the traditional conclusions from contingency theory. We rely on them to address the question whether there are design and behavioral characteristics that are robust (Lin & Carley, 2001, p. 5) – in the sense of stable and flexible enough – to allow for an '*all-seasons'* approach to organizational reliability.[12] This boils down to dealing with paradox. For that reason, we have chosen HRT as our main theoretical framework. HRT, or the study of High Reliability Organizations (HROs) is dealt with abundantly throughout this dissertation. In this introductory chapter, we point out why this framework can provide its usefulness.

3.4.2 HRT relevance

With our research question in mind, it is clear that the study of HROs could be promising. More in particular, there are four reasons behind our choice for HRT as the theoretic framework for studying operational reliability of the incident management process.

A first reason is because it permits to deal with the two dominant organizational dimensions: the structural and the contextual dimension (Pugh, Hickson, Hinings, & Turner, 1968;Pugh, 1973). Both dimensions are necessary to understand what constitutes organizational reliability. A mere structural approach, focusing e.g. on procedures, coordination mechanisms, communication channels, does not take into account social and cognitive aspects. A mere contextual approach, focusing on organization culture, leadership style, self-efficacy etc, however relevant and often ignored, on its own is not capable of explaining/guaranteeing reliability or the lack thereof. This combination normally cannot be found in one theory but calls for an integration of individual theoretical concepts, with incompatibility as a consequence. It is the merit of HRO scholars that they have built a coherent framework that overcomes this shortcoming.

A second reason for our choice for HRT is that HRO as a noun has a great business value. Citing Weick and Sutcliffe: "*In today's context it makes sense for any organization to become more like an HRO. Today's business conditions involve increased competition, higher customer expectations, reduced cycle time, and tight interdependencies. These changes produce environments that are almost as harsh, risky, and unforgiving as those that HROs confront. That being the case, organizations that confront HRO-like environment with HRO-like processes should have more success at learning and adaptation than those who don't*" (Weick & Sutcliffe, 2001, p. 114). If our research is to have some value for the field, it needs to build on concepts with high face validity. We believe this is more important than high scientific rigor in the purest sense, at least as a starting point. A broad interest is an enabler for deepening, fine-tuning and correcting, such theory. It will allow for a broader empirical basis that is indispensable for its generalization and validating on a broader scale.

A third reason for our choice of HRT is its relevance for the study of the reliability of mainstream organizations (as opposed to the organizations under physical threat). Attempts of transposing practices from archetypical HROs (like nuclear power plants, nuclear aircraft carriers, and air traffic control) to mainstream organizations have often been critiqued as too special, too exotic, and too 'far out' for the prosaic world of everyday organizations (Vogus & Welbourne, 2003a, p. 877). In line with Vogus and Welbourne, our study attempts to answer the question under what conditions do 'prosaic' organizations resemble 'exotic' HROs. The popularity of the HRO theme is ambiguous. On the one hand there is an (all-in-all limited) number of publications that aim at transposing HRO insights to mainstream organizations: CEO bandwagon behavior (Fiol & O'Connor, 2003), HRM practices in innovation (Vogus & Welbourne, 2003a), organization change (Ramanujam, 2003), construction industry (Carlo, Lyytinen, & Boland, Jr., 2004;Smart, Tranfield, Deasley, Levene, Rowe, & Corley, 2003), mining (Sammarco, 2002), industry in general (Mascini, 1998;Azadeh, 2000;Cooke & Rohleder, 2006;Aase & Nybø, 2002;Qureshi, Ashraf, & Amer, 2007), Banking (Roberts & Libuser, 1993;Ramanujam & Goodman, 2003;Ramanujam, 2003;Montefusco & Pesapane, 2006;Van Den Eede, Van de Walle, & Rutkowski, 2006), electricity grids (Schulman, Roe, van Eeten, & de Bruijne, 2004;Roe, Schulman, van Eeten, & de Bruijne, 2005;de Bruijne, van Eeten, Roe, & Schulman, 2006;de Bruijne & van Eeten, 2007) and Telecommunications (de Bruijne et al., 2006;de Bruijne, 2006;de Bruijne & van Eeten, 2007). A noteworthy effort has been made to apply the HRO framework to the IT sector (Eisenhardt, 1993;Sullivan & Beach, 2002;Vogus & Welbourne, 2003a;McBride, 2008). A similar effort can be noticed in the field of education (Rossi & Stringfield, 1995;Reynolds, Stringfield, & Schaffer, 2006;Hoy, Gage III, & Tarter, 2007;Bellamy, Crawford, Marshall, & Coulter, 2005). Some single publications on e-government by means of electronic voting (Moynihan, 2004), automobile industry (Drogoul, Kinnersly, Roelen, & Kirwan, 2007), water supply (Roe et al., 2005), science (Baker, Jackson, & Wanetick, 2005), architecture (Carlo et al., 2004), pastoralism (Roe, Huntsinger, & Labnow, 1998) and drug rehabilitation (Cooren, 2004). Some studies are at the edge of archetypical HRO research and more mainstream organization types: Prison management (Babb & Ammons, 1996;Crichton, Flin, & Rattray, 2000), railways (Hale, Heijer, & Koornneef, 2003;Smart et al., 2003;Rosness, Guttormsen, Steiro, Tinmannsvik, & Herrera, 2004;Busby, 2006;Drogoul et al., 2007) and humanitarian relief (Ash & Smallman, 2008;Dougall, Horsley, & McLisky, 2008).

A fourth and last, less sophisticated, reason why we have used HRT is because it 'spoke' to us (Walsham, 2006, p. 325).

4 Complexity

4.1 Decomposing complexity

Since the fifties, the complexity theme holds an important position in literature on organizations - scientific as well as popular. The form however, under which this theme appeared, has differed considerably over the years.[13] In the beginning years, research appeared under other denominators than complexity (see for instance Ashby 1954 for a well-known example). Over the years, the tone also changed from '*defeating complexity'* to '*embracing complexity*' (Figure 1.5). A thread throughout this evolution nonetheless is that organizations had to match the complexity of their environment (Boisot & Child, 1999, p. 237).

The notion of complexity plays a special role in this dissertation. First, it is the setting under study; it is the *object* of our thinking. Second, it is the *subject* of our thinking in the sense that complexity is the lens through which we look at complexity. The frameworks and jargons we use are complex per se. It takes complexity to absorb complexity. Tsoukas calls this second-order complexity as opposed to first-order complexity (Tsoukas & Hatch, 2001, p. 980-981).

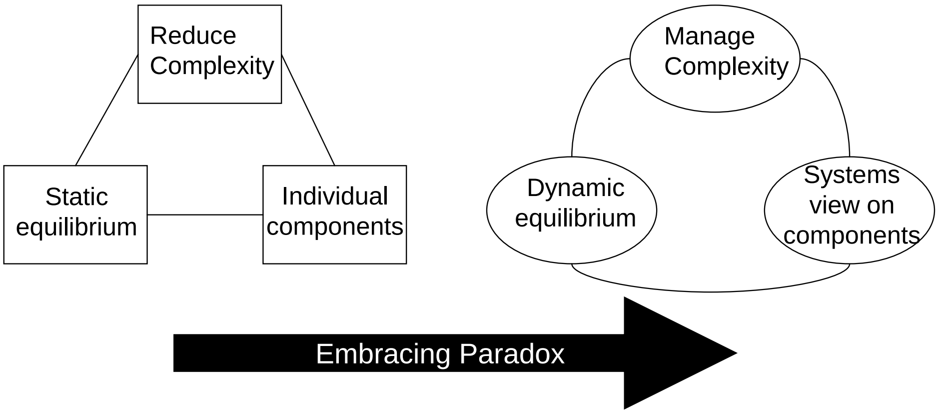

Figure 1.5 - Embracing Paradox

Management and other social sciences are familiar with the terms 'lessons learnt', or 'best practices'. They imply that there is something like a general truth (be it contingent on a certain type of situation) upon which we can draw for the future, actions that should be committed or omitted.[14] This line of reasoning implies that the future is foreseeable, but in many cases, it is not.[15] One of the questions one could ask is "*If you cannot predict the future, is it possible to manage a complex system*?" Longstaff (2003) argues there are two answers to that commonsense question and he leads us to the important distinction between 'complex 'and 'complicated. The first answer is that not everything in a complex system exhibits the same high degree of complexity. The objective hence is to *make* that distinction. The second answer has more to do with hypocrisy than with science. Because the belief that 'predictability rules' is the null hypothesis, adhering the alternative hypothesis by saying that 'unpredictability rules', is detrimental for one's career (Longstaff, 2003, p. 11). Much hypocrite as this might seem, it is nevertheless an important motive behind human behavior and hence worth noticing and taking into account when studying reliability.

Without prejudice to the above, we believe that a distinction between complex and complicated can and should be made. If one makes this distinction, one could manage our contemporary systems by concentrating on the complicated issues, threads, themes in the systems. The complex counterparts can be observed – maybe one could even try to understand them – but only by acknowledging the fact that under no circumstances they can be managed in the traditional sense of controlling and leading (Fayol, 1916).

On the other hand, an organization must embrace complexity and keep it as high as possibly acceptable without crossing the thin line between complexity and chaos.

So it will have become clear by now that complexity has two sides; that there are two ways of approaching the topic of complexity (Ahlemeyer, 2001, p. 59): "*One can describe complexity as the problem, and then look for solutions. Complexity, after all, makes things difficult, and it may easily get out of control. In this perspective, nothing is more welcome than an effective technique of reducing complexity. Or one can conceive of complexity as a solution, a solution for a problem yet to be described. Complexity then is not an unintended side effect of an otherwise complex world, but a form of the world itself, a mode in which the world deals with itself. In this perspective, a simple reduction of complexity which does not at the same time refer to new* *complexity is to be avoided*”. By analogy with risk, we label the first type ‘downside complexity’, the second ‘upside complexity’. Downside complexity stands for the negative consequences of complexity. It appeals to the inherent peril of waste of energy, frustration or else even organization- or system collapse. Upside complexity appeals to the positive aspects of complexity. It stands for opportunity (chance) to yield a higher reliability than without complexity.

4.2 Measuring complexity

In literature we have found no complexity measure upon which there is a general agreement or that is broadly used to determine organizational complexity. We believe the reason is – at least in part – that the term is composed of two elements that are not univocal: organizational and complexity. Organizational: can relate to people, processes, products and services; it can address issues that are internally or externally oriented.

The concept of complexity itself can be seen as the number of interactions between components; the degree/intensity at which that happens; the relationship cause-effect can be considered with a delay between both indicating a higher degree of complexity; there is the neighboring notion of complicatedness etc.

Variety offers a good proxy measure of complexity (Boisot & Child, 1999) but an even better proxy is the complexity index (Ashmos, Duchon, & McDaniel, Jr., 2000).

4.3 Managing complexity

Whether an organization prospers or merely survives, depends on how it manages complexity (Ahlemeyer, 2001;Ashmos et al., 2000;Beard, 1978;Berniker & Wolf, 2001;Klatzky, 1970;Meyer & Trice, 1979;Stacey, 1996;Stengers, 2004;Van Uden, 2005). Complexity can transgress into chaos if it is not kept within a certain range (Bennet & Bennet, 2004). Since complexity refers primarily to the number of decisions that need to be made and the number of factors that need to be considered when making these decisions, this calls for a tremendous effort. According to Cannon (1995, p. 96), as the cognitive capabilities of most people are limited to handle only a limited number – working memory capacity is said to be five plus or minus two – this poses a problem to dealing with complexity. However, successful organizations seem to accomplish a manageable complexity-level. For this, they have a set of strategies. They are dealt with next.

Requisite variety

Requisite variety refers to Ashby’s (1962) argument that it takes internal complexity to cope with external complexity. In this sense, a complexity absorption response involves holding multiple and conflicting portrayals of the variety in the environment (Boisot & Child, 1999, p. 238). “*Managerial responses to complexity from the absorption perspective would include the development of multiple and sometimes conflicting goals, the importance of a variety of strategic activities, more informal and decentralized structural / decision making patterns, and a wide variety of interactions and connections for decision making*” (Ashmos et al., 2000, p. 581).[16] Absorbing complexity means they “*hold multiple and sometimes conflicting representations of environmental variety, retaining in their behavioral repertoire a range of responses, each of which operates at a lower level of specificity*'' (Boisot & Child, 1999, p. 238).

The notion of requisite variety – despite its high face validity – is not without problem. For instance, it is obvious that this need of requisite variety should be balanced with the limited cognitive capabilities (supra) and the need of dealing with tight coupling. It has been reported in military settings (Dov & Gil, 2003, p. 853) that is done by using a shared a meta-script system that resulted in similar representations of the environment, i.e., conceptual convergence. This reduces requisite variety to cognitively manageable proportions.[17] Another caveat concerns the contradiction between requisite variety and trust. "*[I]t is argued that the management of requisite variety must be accompanied by attention to power relations and the development of practical wisdom, since diversity inevitably means differences in belief and opinion within groups and potential increases in anxiety, which while necessary for innovation may often work against the building of high levels of trust and shared understanding that may be required for such innovation*" (Moss, 2001, p. 11/20).

Simplification: codification and abstraction

At first sight in contradiction with the techniques of increasing requisite variety, are the set of techniques that aim at streamlining the observed reality. They do so by codification (specifying categories to which data are assigned) and abstraction (limiting the number of categories that need to be considered in the first place) (Ashmos et al., 2000, p. 581). Popular tools include Balanced Scorecards and Key Reliability Indicators. The opposing phenomena of Requisite Variety and Simplification tend to occur together in organizations and as such, they are a nice example of paradox. This a priori so, because both phenomena exhibit dynamic characteristics. Organizations, for instance, tend to become simpler over time (Miller, 1993) and have a propensity to increase variety. We refer here to organization growth models like the one of Greiner (1972) where organizational variety increases in the wake of the solutions for organizational crises.[18]

Sinks

The presence of 'sinks' that absorb external impacts and buffer subsystems from change will make the system less complex (Longstaff, 2003): "*For example, when the price of an input to a product goes up but the firm can immediately pass this on to consumers this acts as a sink protecting the firm from the impact of the price increase and makes it unnecessary for it to build a complex system for response*" (Longstaff, 2003, p. 17).

Shortening feedback loops

"*Positive and negative feedback (and feed forwards) loops of different lengths. Long feedback loops, with communication going through many agents or subsystems tend to be more complex*" *(Longstaff, 2003, p. 16-17).*

Also the connectivity, 'the extent to which agents or units are all connected or are connected through hubs' will increase the complexity of the system" (Longstaff, 2003, p. 16-17).

A self-creating paradox – Acknowledge the boundaries

At several occasions in this dissertation, we stress the importance of looking 'beyond the boundary'. Paradoxically enough, this does not imply that boundaries have to be omitted. On the contrary, they are needed: how else can one look behind them? However, there is more: in a field that is as complex as reliability, taking a broad perspective is a merit, but it is also a vice if there is no partitioning of knowledge. "*We also realize, however, that some partitioning of* *knowledge is necessary and some boundaries to this knowledge must be set if meaningful progress in summarizing and classifying pertinent knowledge is ever to be made*" (Koontz, 1980, p. 183).

Hence, our plea to acknowledge the boundaries, even though the aim of our approach – and especially its systems thinking component – is to cut across the boundary perspective of organizations. Boundaries are and remain vitally important for organizational structure. '*You can't live with them, you can't live without them*' In search of a balance, the key would seem to be to recognize the boundaries, but to make them as transparent as possible. "*To see them as necessary 'net curtains', not 'heavy drapes'*" (Wolstenholme, 2003, p. 9).

Complexity and variety

Referring once again to the models of organizational growth (Greiner, 1972), we believe that over time organizations/systems are capable of handling more and more complexity (Boisot & Child, 1999, p. 238). They "*[…] differentiate internally, acquiring sophisticated data-processing capabilities as they do so.*" *[…]* "*With growth and specialization comes an ability to handle an ever wider and varied range of internal representations of the external environment*" (Boisot & Child, 1999, p. 238). [19]Ashby's Law states that systems exhibiting a high degree of variety will be better in dealing with complexity. The variety of control measures must match the variety of disturbances (Gazendam & Jorna, 1998, p. 5).

Complexity , resilience and structure

If a complex system exhibits resilience it will bounce back from changes and is more likely to be stable in the long term (Longstaff, 2003, p. 16-17). Lin and Carley (2001, p. 34) state they have found empirical evidence that in response to crises, organizations should move to complex structures with greater resource access.

Complexity is a young field searching for laws, theories, and principles that can be used to build a structure and a discipline (Bennet & Bennet, 2004, p. 285). Nevertheless, sufficient knowledge is present to understand that if an organization wants to prosper, or merely survive, such depends on how it manages complexity. The inconvenience is that complexity can transgress into chaos if it is not kept within a certain range (Figure 1.6). This calls for a tremendous effort and the application of a strategy to accomplish a manageable complexity-level: pursuing strategic chunking, sequential elaboration, organizational specialization/coordination and intermediate measures of reliability (Cannon, 1995). It is our opinion however that these strategies seem to aim at a reduction of complexity, and not its management.

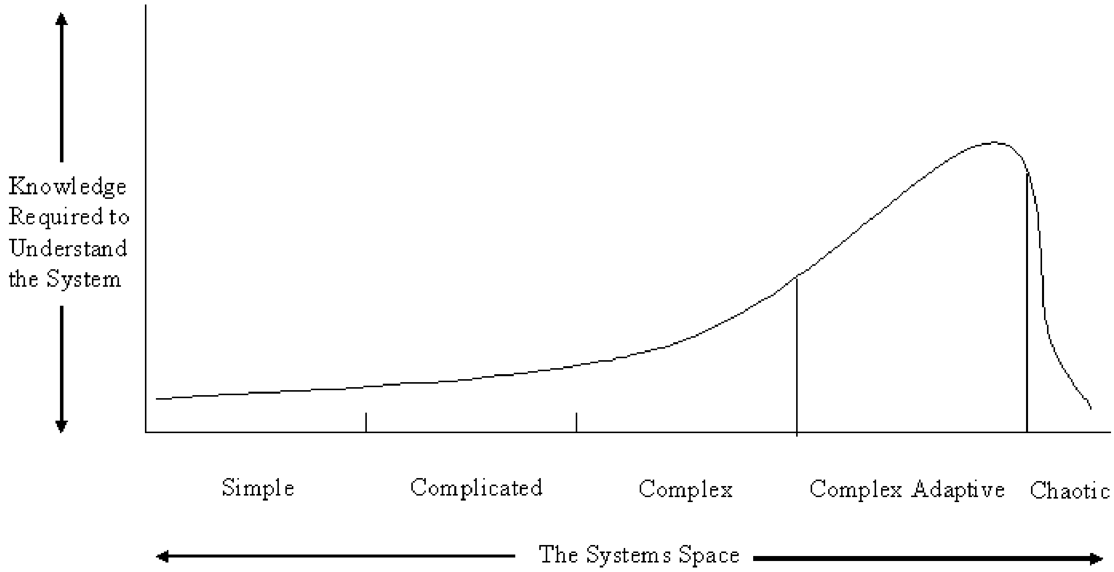

Figure 1.6 - Systems Space

Simple	*Complicated*	*Complex*	*Complex Adaptive*	*Chaotic*
Little change over time	Large number of interrelated parts	Large number of interrelated parts	Large number of semi-autonomous agents that interact	Large number of parts that interact
Few elements	Connections between parts are fixed	Nonlinear relationships and feedback loops	Co-evolves with environment through adaptation	Behavior independent of environment
Simple relationships	Non-organic	Emergent properties different than sum of parts	Varying levels of self-organization	Minimal coherence
Non-organic	Whole equal to sum of its parts	May be organic or non-organic	Partially ordered systems that evolve over time	Emergent behavior dependent on chance
No emergent properties	No emergent properties		Operates in perpetual disequilibrium Observable aggregate behavior Creates new emergent properties	
Knowable and predictable patterns of behavior	Knowable and predictable patterns of behavior	Patterns of behavior difficult to understand and predict	Patterns of behavior may be unknowable but possibly fathomable	Random patterns of behavior

Table 1.2 - Properties of System Dimensions (Bennet & Bennet, 2004)

The future is truly unknowable and therefore we must learn to live and deal with uncertainty, surprise, paradox, and complexity (Bennet & Bennet, 2004, p. 297-298). In this dissertation we therefore do not aim at reducing complexity – like suggested by Cannon (1995), but at keeping it as high as possibly acceptable without crossing the thin line between complexity and chaos (Table 1.2) and as suggested in the Cynefin framework (Kurtz & Snowden, 2003).

5 Coupling

5.1 Decomposing coupling

Interdependence or coupling is the degree to which organization components – whether they be applications, functions, departments or individuals – depend on each other. Loose-coupling means that the components can operate independently from one another. Tight-coupling means a continuous interchange of information, goods or services. Coupling has many dimensions. Thompson (1967), for instance, in his framework of departmental interdependence, classifies in three types of interdependence: pooled, sequential and reciprocal interdependence. Another dimensional framework is to distinguish between piece, batch and continuous production. However, no matter what framework is used to define tight or loose coupling, essential is the question about availability of buffers, resources, time, and information that can enable recovery from failures. The looser components are coupled, the more possible recovery paths exist. The tighter they are coupled, the less an organization disposes of ways to recover (Berniker & Wolf, 2001). Table 1.3 shows the differences between tight and loose coupling from a technical perspective.

Tight-coupling characteristics	*Loose-coupling characteristics*
Time-dependent processes which cannot wait	Processing delays are possible
Rigidly ordered processes (as in sequence A must follow B)	Order of sequence can be changed
Only one path to a successful outcome	Substitution is available
Little slack (requiring precise quantities of specific resources for successful operation).	Slack in resources is possible, buffers and redundancies available

Table 1.3 - Tightly vs. loosely-coupled processes (Perrow, 1999, p. 92-93)

From the above one might conclude that tight-coupling is not a choice as it is the consequence of requirements of the production or service delivery context. This may be true in part, but it is also true that poorly run, financially less successful organizations will have fewer resources available for e.g. preventative maintenance, replacement of aging equipment or modernization and less slack operating resources (Berniker & Wolf, 2001). Besides, as Wolf (2001) notes, such organizations may be forced to operate with tighter coupling as a result of cost cutting measures, meaning that tight-coupling may be a managerial decision based upon budgetary stress or profit targets.

We do not suggest a categorical approach to loose coupling, independent of the interactive complexity of an organization's context. Stronger even, we acknowledge that an exclusive focus on reducing tight-coupling (e.g. by increasing redundancy) may lead to normal accidents if this is done in a setting that merely addresses single loop learning (Bain, 1999).

5.2 Measuring coupling

One way of measuring coupling is by looking at the resources that are available to the whole or parts of an organization. Berniker and Wolf (2001), for instance, use Return On Assets (ROA) as a measure of resource availability. They formulate an interesting remark concerning the relation between tight coupling and slack when they see tight coupling as a management decision and not as something that emerges independent of free will. "*…as Perrow argues, poorly run organizations will have more discrete errors that are available for unexpected interactions that can defeat safety systems and thus will be more prone to 'system accidents' as he refers to normal accidents. Less financially successful organizations have fewer resources available for operational exigencies such as preventative maintenance, replacement of aging equipment or modernization and less slack operating resources. Poor financial reliability can also trigger risky actions including the use of low-bid outside contractors. But secondly, and Perrow does not note this, poorly run or financially starved organizations may be forced to operate with tighter coupling as a result of cost cutting measures. Tight coupling may not be just a requirement of the manufacturing process, but may be a managerial decision based upon budgetary stress or profit targets*" (Berniker & Wolf, 2001, p. 22).

5.3 Loose Coupling Theory (LCT)

The basis and trigger for this section is an article by Karl Weick (Weick, 2004), in which he links Loose Coupling Theory (LCT) to high reliability theory (HRT) over normal accidents theory (NAT). For this he takes Snook's (2002) friendly fire analysis as a starting point. Weick synthesizes this analysis as "*reliability [that] had been achieved through a combination of differentiation, specialization, training, culture, and redundancy. These efforts loosened system coupling and made tasks more linear. But these very same moves toward higher reliability heightened vulnerability to misidentification when units were rejoined under conditions of tight coupling and interactive complexity*" (Weick, 2004, p. 30). Since NAT is a theory on the causation of a specific type of accidents, it is hard to assess directly the impact of complexity and tight-coupling on overall reliability. Since HRT discerns strategies enhancing overall reliability, it is difficult to evaluate directly the proneness of these strategies to specific, normal accidents. Therefore, the effects of one theory's independent variables on the other theory's dependent variable will be assessed indirectly. The questions asked become: Which effects do complexity and tight-coupling have on the effectiveness of reliability-enhancing strategies discerned by HRT and, hence, on overall reliability? How do HROs' reliability-promoting strategies impinge on complexity and tight- coupling and, hence, on normal-accident proneness (Rijpma, 1997b, p. 16)?

5.3.1 In search of reliability

As we have put forward in the preface to this dissertation, we do not aim at focusing on the bricks. It is the mortar that interests us most. The things that become visible by relying on an alternated combination of observation and reasoning. It boils down to searching for a story-line, based on what we see, hear or read and what our mind does with these components. It is this story-line that then can be checked against the observation and (other) theories in order to falsify or validate the hypotheses that go with the story.

We are certainly not the first to take this approach. Our source of inspiration is Scott Snook who with his *Friendly Fire* (2002) has shown us his journey in search of a story line that had the potential to explain what happened in such a way that it could be abstracted from too specific a context and transposed to a generic framework. Something in which he succeeded magnificently by continuously, and over and over again looking at the same thing, but always from different perspectives: individual, team, organizational; technological, human factor, procedures; organization design; process, product; time, place; and finally complexity and coupling. With the development of his Practical Drift, Snook found his story-line. It took a *tour-de-force*, but he did it (Weick, 2001a).

The story of reliability is complex. Reliability is a '*dynamic non-event*' (Weick, 1995), because "*organizations have to continuously manage and adapt to a changing and uncertain environment, while producing a stable outcome, the avoidance of accidents*" (Intosh-Murray & Choo, 2002, p. 6). The tools and rigor that will have to be applied will be more comprehensive. A mere reduction will not suffice. Neither will it help much only to take a different perspective in the style of Snook. More is needed here. Our framework has to be wide and rich enough to allow for insights to emerge by means of the alternation of observation-ratio combinations. On the other hand, it has to be clear and acquainted enough to allow for the emergence to take place and to make the conclusions interpretable. We rely on LCT to accomplish this task.

5.3.2 Relevance

Like Orton and Weick (1990) have pointed out via their literature review, Loose Coupling Theory (LCT) incorporates a multidimensional perspective to the organizing process. "*Organizational participants are linked simultaneously by bureaucratic and cultural ties, by functional and resource interdependencies, by vertical and horizontal linkages, etc.*" (Beekun & Glick, 2001a, p. 229). Numerous possible combinations of coupling emerge which makes it – both from an academic and practitioner's perspective – an appealing phenomenon, but which at the same time holds a latent danger when researched or applied wrongly. "*Unless prescriptive statements identify precisely which dimensions should be loose or tight, managers may implement coupling inappropriately*" (Beekun & Glick, 2001a, p. 229). Bottom-line is to make a scan of the organization through the lens of coupling to gain a deeper understanding of it. We state that LCT is the ideal scalpel for organizational dissection, before which all other instruments pale.

Therefore, we rely on the literature on loose coupling as an analytical tool to help us understand the dialectical discussion that has surrounded organizational reliability. The concept of loose coupling allows us to move in a more subtle and judicious direction toward understanding what reliability means. As such, we use the loose coupling perspective not only as an organization model to understand the degree to which organizational elements are linked, but as a cognitive model to understand how Incident Management workers interpret, label, enact, or otherwise make sense what occurs in their environments.

5.3.3 Identification

The thinking in terms of tight and loose coupling originated from Robert Glassman (1973) who applied it in the context of biological systems. Soon it became clear that the concepts could prove very useful in other domains as well (Longstaff, 2003, p. 30-31) since coupling in essence is about organizing.

Coupling

Coupling is a tough concept. It is used with eagerness by many organization theory scholars. However, there is no univocal interpretation of tight-coupling (Orton & Weick, 1990, p. 203). A turning point in the development of Loose Coupling as a theory is the 1990 Orton and Weick article in which the authors examined approximately 300 studies that invoke the concept of loose coupling (Orton & Weick, 1990, p. 204). They divided the findings of their desk survey into five different categories which they called 'voices': (1) causation, (2) typology, (3) effects, (4) compensations and (5) organizational outcomes (Figure 1.7). They have linked them in a "*preliminary theory of the loosely coupled system*" (p. 204), a theory they have relied on to discuss some appealing organizational issues. We do not build on all aspects of LCT equally, but limit ourselves to those aspects that are most promising when applied to the context of management paradigms.

Loose Coupling

In fact, the phrase 'loose coupling' is a challenge because loose and coupled are opposites. But the dynamics that emerge from the duality between the two components (loose and coupling) make it in an interesting concept that is often more useful to deal with complex reality than the straight-forward notion of 'tight coupling'. Loose coupling implies some kind of mixture of independent interdependence and dependent independence. Things are coupled but loosely, things are loose but yet coupled in a way. In this respect loose coupling is not the other end of the spectrum of tight coupling (Orton & Weick, 1990, p. 205). The notions of distinctiveness and responsiveness are used to learn about the way systems are coupled. Furthermore it is important to notice that asserting that a system is loosely coupled is to predicate specific properties and a specific history to the system, rather than an absence of properties (Orton & Weick, 1990, p. 219). "*Coupled events are responsive, but each event also preserves its own identity and some evidence of its physical or logical separateness*" (Weick, 1976, p. 3). This happens suddenly, occasionally, negligibly, indirectly and eventually. (Orton & Weick, 1990, p. 203) Longstaff (2003, p. 31) points out: "*A system could be tightly coupled if its components share many variables or the link between the variables is very strong. Engineered systems with automatic controls are said to be tightly coupled (if A happens then B is the automatic and immediate response)*". Weick continues (Weick, 1976, p. 3): "*It might seem that the word coupling is synonymous with words like connection, link, or interdependence, yet each of these latter terms misses a crucial nuance. […] Loose coupling also carries connotations of impermanence, dissolvability, and tacitness all of which are potentially crucial properties of the 'glue' that holds organizations together. Another way of looking at the coupling of systems or organizations is to study the behavior of their components. "Tightly coupled organizations are those where any change in one component (individuals or subsystems) of the system will* *engender an immediate response from the other component(s)*" (Longstaff, 2003, p. 31). Orton and Weick point out that several forms – they call this the voice of typology – of coupling exist: among individuals, subunits, organizations, between organizations, hierarchical levels, organizations and environments, among ideas, between activities and between intentions and actions (Orton & Weick, 1990, p. 208).

Dialectical approach

Crucial in our discussion about coupling is the insight that 'not tightly coupled' is not the same as 'loosely coupled'. To assert that a system is loosely coupled is to predicate specific properties and a specific history to the system, rather than an absence of properties (Orton & Weick, 1990, p. 219). This dialectical perspective on loose coupling opposes against a unidimensional approach (e.g. by Perrow). By acknowledging the dynamics of the different views that can be developed between the layers of loose coupling (Orton & Weick, 1990) the palette the researcher has at his disposal for his investigation of organizational reliability has become much richer than under a one-dimensional framework. In the words of Orton and Weick (1990, p. 204-205): "*[t]he resulting image is a system that is simultaneously open and closed, indeterminate and rational, spontaneous and deliberate*" (Orton & Weick, 1990, p. 204-205).

This dialectical perspective on loose coupling we have described stems with a Hegelian perspective on Organizations. The dialectical perspective on loose coupling opposes against a unidimensional approach (e.g. by Perrow, 1984). By acknowledging the dynamics of the different views that can be developed between the layers of loose coupling (Orton & Weick, 1990), the palette the researcher has at his disposal for his investigation of organizational reliability has become much richer than under a unidimensional framework. In line with what we have said on the philosophical stand that is needed in management, the possibility of a dialectical interpretation of coupling offers a powerful tool for organization analysis and design.

Reality is not unidimensional, it is even deceiving because easy answers are always available for he/she who is looking for them. Often there is little to win by going to the bone of the causation of the accident, there are more forces present that foster the easy solution in terms of people to blame, technology that did not work, procedures that were wrong etc. The X causes Y direct effect is still the (social) science ideal (Orton & Weick, 1990, p. 218).

What loose coupling is not

Organizations that have thought about (be it implicitly of explicitly) the way their processes are (loosely) coupled are interesting. One should not make the mistake to describe loose coupling as the absence of a management effort and vision to be 'on top of things'. The absence of features of tight coupling does not boil down to being loosely coupled. The problem however is, that "*[W]hen researchers define organizations as monolithic corporate actors, they overemphasize order and underemphasize elements; when researchers define organizations as mere aggregates of individuals, they overemphasize elements and underemphasize order. If researchers begin with richer definitions of organization, they will arrive at more accurate findings and conclusions*" (Orton & Weick, 1990, p. 216 & 218).

Relevance

The concept of loose coupling is a powerful yet underestimated one. Like Orton & Weick (1990, p. 203) write: "*Loose coupling, however, is a metaphor that has a rare combination of face validity, metaphorical salience, and cutting-edge mysticism, all of which encourage researchers to adopt the concept but do not help them to examine its underlying structure, themes, and implications*". This combination is rare and is an interesting approach to systems thinking, to looking beyond the boundary of the easily observable. The thing is that loose coupling all too often is taken for granted, a bit in the same way the notion of complexity is. Seldom is it asked what exactly is meant by it but everybody seems to be satisfied with a vague description. A comprising definition is lacking and is even not desired. At best a circumscription by means of examples and cases is the only description available.

5.3.4 Managing coupling

Now that we know what coupling (loose and tight) is, we should ask ourselves once again whether loose coupling is worth striving for. One thing is certain: the Coupling concept is in an interesting one. Many scholars have tackled it, all from different viewpoints, but nobody seems to have dealt with it the way Karl Weick and his co-authors have (Weick, 1976;Orton & Weick, 1990). Their contribution is important because of their multidimensional study of the idea. They seem to have taken coupling from the concept level to the construct level by pointing out what causes coupling, what typifies it, what its effects are, how it compensates and what can be expected as results.

Weick (1976) argued that loosely coupled systems could more accurately register their environments through requisite variety. Registering improves when elements become more numerous and the constraints among them weaken (Orton & Weick, 1990).

Anyway, it seems that the benefits of loose coupling cause some drawbacks to emerge as well. These drawbacks are often found in form of a lack of traditional control mechanisms.

"*As suggested earlier, it may not be the existence or nonexistence of loose coupling that is a crucial coupling that is a crucial determinant of organizational functioning over time but rather the patterning of loose and tight couplings*" (Weick, 1976, p. 12).

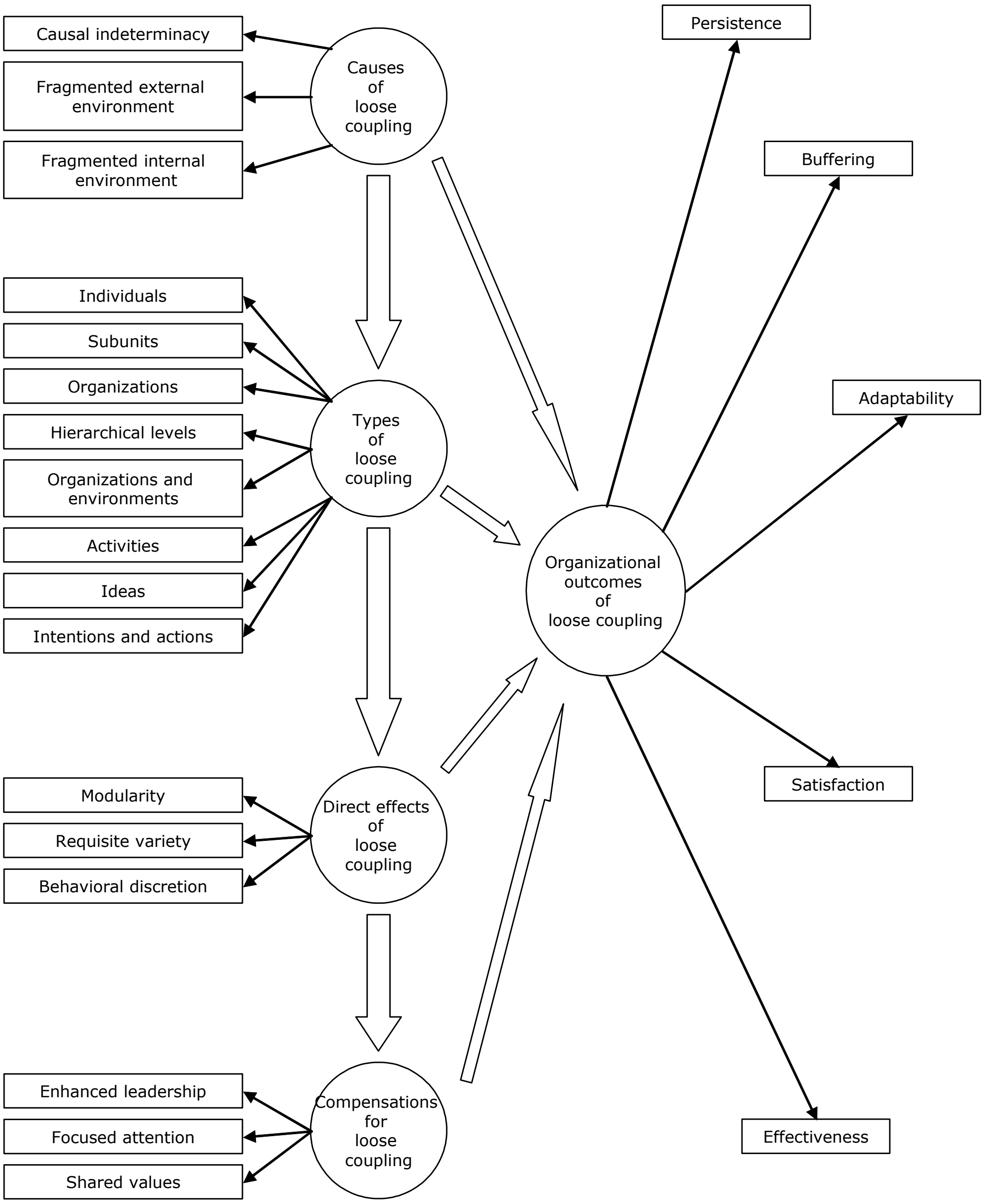

Figure 1.7 - Loose Coupling Theory (Adapted from Orton & Weick, 1990, p. 217)

The question remains *how* this lens and toolkit from LCT can contribute to this dynamics. The answer is double. First, its approach goes to the essence of what organizations are: relating 'things', be it people, concepts, facilities, processes, etc.). Second, the phrase loose coupling has a paradoxical nature since it implies a tension between determinacy (coupling) and indeterminacy (looseness) (Beekun & Glick, 2001b, p. 228) And it is this tension, this suggestion of a middle ground between the centrifugal tendencies of entrepreneurial creativity and the inertial tendencies of formal administrative systems (Lubatkin, Florin, & Lane, 2001, p. 1370), that keeps the balance between an innate tendency to organize things in a tightly coupled (closed, rational, deliberate) way (Boone & van Witteloostuijn, 1995) on the one hand, and an on the field 'practical drifting' towards loose coupling.

Therefore we fully agree with the following assertion from Weick and Orton (1990, p. 218): "*Loose coupling may be able to do for the study of organizational structure what bounded rationality did for the study of decision making. By recognizing and explaining how decisions are* *made by humans with limited interest, time and energy, Simon required studies of decision making to move into more subtle, more detailed, and more enigmatic directions. The concept of loose coupling, with its recognition of numerous structural dimensions, its emphasis on simultaneous coupling and decoupling, and its portrayal of structures as malleable through managerial intervention, similarly forces researchers to move more deeply into the human workings which underlie organizational structure. In the same way that bounded rationality has led researchers to study the processes of decision making, rather than merely the outcomes, loose coupling may lead researchers to study structure as something that organizations do, rather than merely as something they have*". It is for this reason that we intend to rely heavily on LCT for the discussion of our findings.

6 Research Questions

Our dissertation builds on the research on High Reliability Organizations (HROs) to understand and manage reliability and risk. For that reason, we transpose lessons learnt in the typical high hazard domains of a Nuclear Power Plant (NPP) to the more mainstream, though still risky, domain of Information Technology (IT) in the field of Banking. We do so in the context of the operational risk management efforts in view of the incident management process[20] of a large Western-European NPP on the one hand, and an important European financial institution, on the other hand. For clarity, we wish to stress that we leave the technology and its tight-coupling and interactive complexity, like described (for instance) by Thompson (1967) and Perrow (1999) out of the scope of our research. We focus solely on the handling of the incidents – not on the incidents themselves.

6.1 Are the organizations HROs?

Research on reliability is typical of high-hazard manufacturing settings, especially the ones that heavily build on complex technologies like civil and military aviation and nuclear infrastructure, oil refinery or transport over sea. The primary focus here is safety in the strictest sense: safeguarding staff and infrastructure from calamity. As is shown in Chapter 2, these organizations over the years have gained considerable expertise and can take pride in an impressive track-record. Creed et al. distinguish HROs from what they call TEOs – Trial and error organizations (Creed, Stout, & Roberts, 1993, p. 70). These are organizations that have the luxury of learning through trial and error whereas in HROs the stakes are too high and any mistake immediately is punished by catastrophe. Such catastrophe can be financial (severe loss, even Bankruptcy), human (casualties) or a combination of both. This distinction is easily made in theory, but much harder in practice. A first reason is that many organizations that cannot be labeled HRO (because they lack the physicality that underlies this organization type) can be labeled with the adjacent notion of High Reliability Seeking Organizations (HRSOs) (Vogus & Welbourne, 2003a). Ericksen and Dyer (2005) label any organization that is confronted with these tight coupling and interactive complexity as *reliability-seeking organizations*, while Vogus and Welbourne (2003a) seem to reserve this term for these organizations on the condition that they are not confronted with the physicality of technical infrastructure (and endangering life). However, because of the relative obscurity of HRSO as a term, we continue to use the more familiar HRO nominator. A second reason is that HROs do make errors, smaller ones mostly, but at times also not so small ones. What is interesting however is the way these errors are dealt with. A first particularity in this respect is that the organization takes learning from errors (and near-errors) seriously. In our Learning Organization era, many an organization posits it learns from errors, but in the business-as-usual mentality, this is merely a slogan. A second trait of HROs, and this is an even bigger discriminator from TEOs, is that errors do not disable them.

Our research aims at linking high reliability literature from physical high-risk settings to more mainstream economical high-risk settings (in our case a financial institution).

Therefore the issue whether the organizations we study bear the HRO hallmarks is relevant. In this respect, the first question our research needs to answer is:

Are the organizations we study HROs? **[RQ1]**

This question applies particularly to the Bank as mainstream and non-archetypical HRO, but does not take for granted the HRO compliance of the NPP and will look for empirical underpinning of this proposition. To answer the question whether the organizations we study are HROs, we split it into three sub-questions.

- Are the HRO properties as described in literature observable in both organizations? [RQ1-1]
- Are the same constructs observable in both organizations? [RQ1-2]
- Has the NPP (as an archetypical HRO) the highest values on HRO properties? [RQ1-3]

These questions may seem obvious but we dare to doubt this.

6.2 What constitutes high reliability?

A second question that is relevant in the field of reliability studies and that our research addresses is what constitutes high reliability? What makes one team more reliable, more performant than another team? Which contextual and/or structural dimensions contribute to high reliability? In other words: is there something like an ideal '*reliability cocktail*'? In addition, how do these dimensions (or constructs) interrelate? Can a non-archetypical HRO and archetypical HRO learn from each other? With this second research question, we analyze the interrelationships that exist between the different determinants and wish to come to an integrating framework that has the potential of contributing to the explanation of reliability.

The second research question hence becomes:

What constitutes high reliability? **[RQ2]**

To answer this second research question, we split it up into three sub-questions.

- Do the HRO and SeMa constructs positively influence process reliability? [RQ2-1]
- Is there a difference in the reliability cocktail of a Bank and a NPP? [RQ2-2-2]
- Is there a difference in the reliability cocktail of one team, compared to another? [RQ2-3]

7 Structure of this Dissertation

Following this introductory chapter – and with our research questions in mind – we next present a review of literature on HRT and adjacent theories (Chapter 2). After that, the methodology framework underlying our research is depicted (Chapter 3), in order to explain why and how we have proceeded to the reconceptualization of what constitutes high reliability organizing (Chapter 4). The result thereof is a conceptual model, with its underlying propositions and hypotheses (Chapter 5). Subsequently, this conceptutalized model is empirically tested and analyzed (Chapter 6) and its results discussed (Chapter 7). A final chapter concludes on and answers the research questions raised and points out this study's contributions and limitations (Chapter 8).

Chapter 2 Literature Review

It is the theory that decides what we can see
Albert Einstein

1 Introduction

This chapter builds the theoretical framework that is necessary to examine and understand organizational reliability. The theme this framework is built around is High Reliability Theory (HRT), but its study is enhanced with constructs that put it in a wider perspective, the perspective of organizing itself.

Since Fayol (1916) we know that management – i.e. management's functions – is about planning (*prévoir*), organizing (*organizer*), leading (*commander*), coordinating (*coordiner*) and controlling (*controller*). Chester Barnard (1938) – later followed by Peter Drucker (1974) – added to this that management is about finding a balance between efficiency (doing the things right) and effectiveness (doing the right thing). Together, these ideas are at the core of organization theory. "*They [i.e. management functions] are the basic aspects of management that have a high degree of universality among different enterprises and different cultures. By using the functions of managers as a first step, a logical and useful start can be made in setting up pigeonholes for classifying management knowledge*"(Koontz, 1980, p. 183). Later on, System theorists (See De Leeuw, 1982 for an introduction) have added to these '*pigeonholes'* a systems view, which encompasses a holistic approach to organizing and organization and which reserves a special place for the management of learning and knowledge.

Despite of the high face-validity of this classification, we feel the essence of management is not captured by these categorizations. Although these activities certainly are what one thinks of when talking about what a manager does, they are not at the heart of it. What drives leading, controlling, planning, coordination, efficiency, effectiveness, learning and knowledge is a necessity to confront the unknown. All the aforementioned activities are determined by it. We state that organizing is looking for ways to enter uncharted territory. Man has developed tools to help him with this task: rules and regulations, reporting, planning, meetings, etc. (Daft & Lengel, 1986).

Unfortunately, there is no ideal-type description of organization like the bureaucracy formulation by Weber (1968). So one has to help oneself by means of approximations: "*Formal organizations are three things at once: contexts within which individual action takes place; sets of rules in the form of propositional statements; and historical communities*" (Tsoukas, 2000). This chapter wishes to go a little beyond these approximations, applies insights, concepts, and constructs from a wide range of disciplines to the study of organizational reliability.

If one looks back at cases of organizational unreliability, one always has the idea the mishap could have been prevented had this or that been done or omitted. In addition, often this investigation finds the same cause: human error. It has been argued that 80% of all accidents can be attributed to a human mistake, in one way or another (Reason, 1997). The question arises however, whether this is really the case. Is it not so that error investigations stop when they reach the black box they call the human mind? The assumption taken in this study is that it are not so much the humans that are in error, but the organizations and the procedures that shape them. So whenever the root-cause analysis ascertains it has found what has gone wrong, it is always worthwhile to keep in mind that other and more hidden elements are involved. It is precisely the objective of this literature review to '*unhide'* these hidden elements. They are studied throughout this chapter; we name them, organize them around a taxonomy and connect them to each other or to related or non-related elements (Pearson & Clair, 1998).

To this end, we focus on High Reliability Theory (HRT)[21], a theory that seems to be really well suited for dealing with the complexity inherent to reliability. We do so by juxtaposing it against Normal Accident Theory (NAT), since both bodies of research share the same basic assumptions regarding the degree of coupling and interactive complexity. Ever since the eighties, these two sets of theories have dominated the discussion on organizational reliability. On the surface, both theories can be characterized as a pessimistic '*accidents must happen*' and an optimistic '*accidents can be avoided*' theory respectively. Remarkably, the origin of both NAT and HRT lies in one and the same publication from 1982, a book on the human aspects of the nuclear meltdown at the 1979 Three Mile Island power plant (Accident at Three Mile Island: The Human Dimensions1982). Both Charles Perrow, whose work later culminated in his influential 'Normal Accidents' (Perrow, 1999, first edition from 1984) and Todd La Porte, founder of the research group at Berkeley which has since conducted research on highly reliable organizational reliability, contributed a chapter. Both authors laid the foundations for two major ways of thinking about accidents and reliability which, subsequently, were played off against one another (Rijpma, 1997a, p. 15).

In the remainder of this chapter, we argue that this juxtaposition is not completely appropriate and that there are better ways of studying the reliability phenomenon. Indeed, by contrasting HRT against NAT, HRT's potential as well as its shortcomings, become apparent. In that respect, the notions of (interactive) complexity and (tight) coupling are of particular importance since they play a prominent role in HRT as well as in NAT. For this purpose, first both theories are studied in more detail in the two subsequent sections (Sections 2 and 3), after which a synthesis emerges in Section 4. Next, section 5 introduces SenseMaking as an additional set of constructs that is considered useful for the explanation of organizational reliability. Because of the vocation of this dissertation, we add to this the study of the role of the fit between the Information Systems (IS) and the Incident Management process they are meant to support. This study is the subject of the last section in this literature review (Section 6).

2 Normal Accidents Theory (NAT)

Society as a whole in general and separate organizations or systems in particular, face a paradox. On the one hand, they become more and more powerful and on the other hand, they become more vulnerable to threats than ever before. This is the basic premise underlying the theorizing on organizational reliability initiated by Charles Perrow in his seminal 'Normal Accidents' publication

(1999, first edition 1984) and that has become known from then on as Normal Accidents Theory (NAT). Even though Perrow is NAT's founding father, the theory has been given a first (thorough) empirical underpinning and brought to maturity by Scott Sagan (1993).

NAT posits that accidents are a normal consequence of a system's interactive complexity and tight coupling (See: Chapter 1 Introduction). This combination results in yet another irreconcilable structural paradox: *centralization*, the method of dealing with the tight coupling, must be combined with delegation (i.e. *decentralization*), the approach of dealing with complexity (Bierly III & Spencer, 1995, p. 639). The impossibility of a simultaneous centralization and decentralization means that systems that are tightly coupled and are interactively complex are bound to fail. Therefore, from a NAT perspective, the only organizations/systems being inherently reliable are either linearly loosely coupled, linearly tightly coupled or loosely coupled complex (Respectively represented in quadrants 1, 3 and 4 from Figure 2.1).

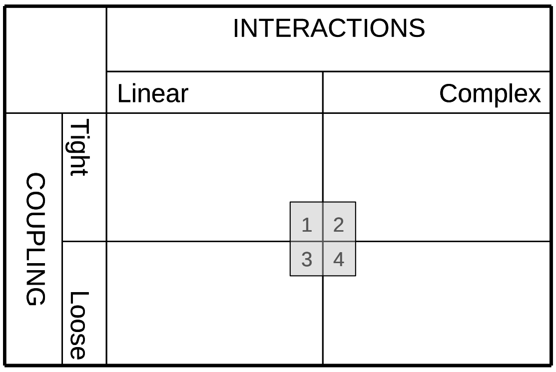

Figure 2.1 - Interaction/Coupling Chart (Perrow, 1999, p. 327)

Both determinants are communicating vessels, though not necessarily balancing. When trying to remediate vulnerability by reducing the tightness of the coupling, very often complexity increases because the development and integration of effective supervising systems (Karvalics, 2002). In this way, the smallest error or disorder can threaten the functioning of the entire system. Because of their central role in the thinking about reliability, this subsection deals with these two determinants of (un)reliability: (1) interactive complexity and (2) coupling, but we do so in a less univocal way than suggested above. We leave room for nuance by not only warning for the danger of the complexity and tight coupling, but equally by drawing the attention to their positive hallmarks. The thesis we put forward is that an organization should not aim at the reduction of complexity and tight coupling, but at managing them. In this respect, we first elaborate on the notion of interactive complexity (2.1). We decompose it and formulate possible strategies for its management. We conclude with an address to NAT's relevance for the study of reliability (2.2).

2.1 Interactive complexity

Complex systems have intricate interdependencies among their various parts and many variables operating at the same time[22] (Longstaff, 2003, p. 15). They exhibit cause and effect that are distinct in time and show emergent behavior. They are typically nonlinear, with surprising compounding effects as a result.[23] Because of their non-linear character, "*adding an element that can be duplicated to the system may cause a shift in the total system that is much greater than the amount added*". As a consequence, complexity can emerge suddenly: "*as soon as you get more than a few* *layers and more than a few variables the complexity starts to go up*" (Longstaff, 2003, p. 23-24). The measure of interactive complexity is the number of ways in which components of the system can interact, which in its turn depends on the number of variables in the system, the number of relationships between the variables and the number of feedback loops through which the variables interact (Cooke & Rohleder, 2006, p. 215). Moreover, it is argued that a complex system exhibits complex interactions when it has unfamiliar, unplanned, or unexpected sequences, which are not visible or not immediately comprehensible. According to Perrow (1999), systems are either 'complex' or 'linear'. Table 2.1 shows the characteristics of both typologies. Although Perrow defines complexity by illustration rather than by rigorous definition, he illustrates his concept of interactive complexity with examples (Berniker & Wolf, 2001, p. 17-18). While not rigorous, the concept of complexity clearly conveys the idea that it is concerned with interactivity and not simply the number of parts, components or subsystems present (Thompson, 1967).

Complex	*Linear*
Component proximity	Spatial segregation (of components and subsystems)
Common-mode connections	Dedicated connections
Interconnected subsystems	Segregated subsystems
Limited substitutions	Easy substitutions
Unfamiliar or unintended feedback loops	Few feedback loops
Multiple and interacting controls	Single purpose regulating controls
Indirect or inferential sources of information	Direct information
Limited understanding of the processes involved	Extensive understanding of process technology.

Table 2.1 - Complex vs. linear systems (Perrow, 1999, p. 85-86;Berniker & Wolf, 2001)

Whereas linear systems are far more easy to manage, complex systems confront us with the problem of 'managing the unexpected' (Weick & Sutcliffe, 2001) due to the unpredictable nature of their interactions. These interactions are called 'baffling' (Perrow, 1999) because they surprise organization members; they are not intended to exist, but yet do exist. "*These [baffling interactions] represent interactions that were not in our original design of the world and interactions that we, as operators could not anticipate or guard against. What distinguishes these interactions is that they were not designed into the system by anybody; no one intended them to be linked. They baffle us because we acted in term of our own designs of a world that we expected to exist-but the world was different*" (Perrow, 1999)[24]. As such, these interactions are very difficult to anticipate.

Conceptually, complexity is the condition of a system, situation, or organization that is integrated with some degree of order but has too many elements and relationships to understand in simple analytic or logical ways. Examples are a team of people, a city, or an ant colony. Internal complexity, from an organization's viewpoint, is its ability to exhibit or contain a large number of states or behaviors (Bennet & Bennet, 2004, p. 290). It is measured by its variety, the number of possible states that the system can have. An organization of high variety has a large number of options and choices of actions it can take to adjust itself internally or when responding to or influencing its environment. If its variety becomes too high, the organization may become chaotic, with no coherence of thought or action (Bennet & Bennet, 2004, p. 290).

In the Perrowian (technical) view, interdependence or coupling is the degree to which organization components – whether they are applications, functions, departments or individuals – depend on each other. Loose coupling means that the components can operate independently from one another. Tight coupling means a continuous interchange of information, goods or services. The degree of coupling can be inherent to the organization's nature, but it can also be the result of management decisions. Such is the case where organizations are forced to operate with tighter coupling as a result of cost cutting measures, meaning that tight-coupling may be a managerial decision based upon budgetary stress or profit targets.

2.2 Relevance

The relevance of Perrow's work has often been downplayed, because most accidents are not caused by the combination of complex interactions and tight coupling. It has even been suggested that some accidents are not caused by tight coupling but by loose coupling (Weick, 2001b). But interactive complexity and tight coupling are strong concepts, independent of each other (Rijpma, 2003, p. 37). This is an explanation why NAT has had (and still has) a tremendous influence on organizational reliability studies. With over 2800 citations (scholar.google.com) it definitely is an all-time citation favorite. We believe its popularity can be explained by (amongst others) its broad applicability, a high face validity, its theory foundation and the spirit of the times.

The dimensions of coupling and complexity, along which the risk bearing of an industry, organization or technology is determined, are universally applicable over sectors, cultures, situations. The degree of interactive complexity and coupling, although hard to objectively measure, is consciously and unconsciously omnipresent, be it in interpersonal relations or conceptual notions. In theory, it is feasible to determine whether a situation is tightly or loosely coupled, or that the interactions between system components are linear or complex.

The combination of the dimensions of interactive complexity and degree of coupling has great potential of explaining (un)reliability. Separately, these dimensions only in part indicate why some type of organization is more prone to accident. Complex organizations are more than linear organizations, and tightly coupled organizations are more complex than loosely coupled organizations. However, some complex organizations seem to be indifferent to calamity whereas others are not. The same goes for some tightly coupled organizations. Only those organizations in the complex-tightly coupled quadrant are the most danger-prone.

Another aspect of NAT that is important for the development of the discipline as a whole is that Perrow used Cohen, March and Olsen's (1972) provocative `garbage can' theory to understand the safety risks in highly hazardous systems (Smart et al., 2003, p. 737). More in particular he drew on one of its two components, namely the emergence of *unclear technology* (the other two being problematic preferences and fluid participation). The high appeal of his Normal Accidents Theory is to a large extent due to the popularizing of the Garbage Can metaphor in the 1970s and its challenging the rational view of organizations as depicted by the classical and early modernist tradition in organization theory (Smart et al., 2003, p. 737). Thus, indirectly, the tremendous appeal and face validity of Garbage Can theorizing has laid the foundation for work like ours.

We live in an era where complexity and interconnectedness are part of our daily lives and get a lot of attention. It is commonly assumed that the evolution of both dimensions proposed by NAT are positively inclined and fast-paced. The NAT message of being risk-averse where nuclear technology, nuclear weapons and other potentially dangerous industries are concerned, finds a fertile soil in the spirit of our times. Therefore, the situations it addresses are easily recognized and what the theory proposes is eagerly acknowledged.

Despite their appeal, these characteristics in themselves are not sufficient as a validation of NAT's hypotheses. A rigorous gathering of data is needed. Unfortunately, there is little empirical evidence that can be found to validate NAT beyond what we have described above. This becomes clear when having a closer look at what a NAT authority like Scott Sagan (2004, p. 16) puts forward as part of the theory's rationale when referring to scholars having applied or further developed the ideas to a much wider range of organizational, personal, and national activities. These include (to give just a partial list), hospital emergency room procedures (Paté-Cornell, Lakats, Murphy, & Gaba, 1997), the origins of the Franco-Prussian War (Nickles, 1999) and U.S. Air Force friendly fire incidents (Snook, 2002). Apart from the last study, literature only addresses NAT superficially. A more recent thorough and successful validation of NAT has been provided by Wolf and Berniker (2008) who tested NAT's application to petroleum refining by linking the occurrence of incidents and accidents to the structure of the organization and its technology.

3 High Reliability Theory (HRT)

Despite NAT's prophecy of doom, some organizations seem to cope really well with errors. Moreover, they do so over a very long time. Researchers from the University of California, at Berkeley (Rochlin, La Porte, & Roberts, 1987), later followed by their colleagues from Michigan State University at Ann Arbor (Weick, 1987), started calling this kind of organizations 'high reliability organizations' (HROs). The collection of their work has become known as High Reliability Theory (HRT). High Reliability Theory is a theory[25] on how a high degree of reliability can be achieved. An organization in which this theory is practiced is called a High Reliability Organization (HRO).[26] HROs are organizations where the risk of calamity is very high, but that yet are successful in their management. HRT disagrees with NAT in its assertion that a simultaneous centralization and decentralization is necessary but practically impossible. Research in HROs argues that such is feasible because of structural and contextual idiosyncrasies, explored in the following subsections. We start by providing a definition of HRT (3.1), a depiction from the perspective of the two main schools of thought (3.2) and an overview of research in the HRO field (3.3).

3.1 Definition

Despite a considerable amount of publications on HROs, there does not seem to be a generally accepted definition of what the phenomenon is, which does not add to their study. We therefore have to rely on derivate definitions and descriptions. The best known[27], in this respect, is the description Karlene Roberts (1990a) gave: "*Within the set of hazardous organizations, some organizations have operated nearly error free for very long periods of time. These organizations are* *'high reliability' organizations (HROs). To identify these organizations one must ask the question, 'How often could this organization have failed with dramatic consequences?' If the answer to the question is many thousands of times the organization is highly reliable. In such organizations, reliability rivals productivity as a dominant goal*" (Roberts, 1990a, p. 101-102). HRO research under the Berkeley HRO Project[28] (as the Berkeley team has come to call it) deals with large, complex organizations that successfully manage advanced technological activities that meet the three following criteria (Rochlin, 1993, p. 15):

1. The activities are inherently complex, in that tasks are numerous, differentiated, and interdependent (Thompson, 1967);
2. The activities meet certain social demands that require reliability at the highest level of service obtainable within present safety requirements, with a desire for an even higher level of activity and a penalty (explicit or implicit) if service slackens (La Porte & Consolini, 1991);
3. The activities contain inherent technological hazards in case of error or failure that are manifold, varied, highly consequential, and relatively time-urgent, requiring constant, flexible, technology-intrusive management to provide an acceptable level of safety to operators, other personnel, and/or the public (Rochlin et al., 1987).

However useful, these typifications say only what HROs are, without explaining why and how. In what follows, we therefore expand this definition by including an answer to the *why* and *how* question.

Essential in the above definitions, is that HROs cannot be easily characterized by static descriptors (Rochlin, 1993, p. 22-23): "*The locus of reliability is in the dynamic of execution and the mobilization of organizational resources more than in any snapshot of organizational form*". Some of the best-known examples are nuclear power plants, aircraft carriers and air traffic control[29]. Indeed, such organizations continuously face risk because the context in which they operate is high hazard. This is so because of the nature of their undertaking, the characteristics of their technology or the fear of the consequences of an error for their socio-economic environment. Elements of such a system can combine in unforeseen ways and when errors occur, they amplify rapidly. In other words: they face complexity and tight-coupling in the majority of processes they run (Vogus & Welbourne, 2003a).

3.2 Two schools of thought: Berkeley and Michigan

In line with the way HRO research traditionally has been organized, this subsection gives a brief overview of the way conceptual and theoretical HRO research has developed. We subsequently deal with the approach taken by the Berkeley and the Michigan school as the most prominent of these descriptions. We start with the way the Berkeley project (New Challenges to Understanding Organizations1993) founding fathers (La Porte, Rochlin and Roberts) have described it. Next, we elaborate on the description of the school of the University of Michigan, Ann Arbor, by Karl Weick and his colleagues (notably Kathleen Sutcliffe, David Obstfeld and Timothy Vogus).

In general, and at risk of oversimplifying, one could say that the Michigan school of thought pays more attention to the notion of culture (as contextual dimension) and that the Berkeley group favors the structural dimensions (e.g. the notion of bureaucracy) (Eisenhardt, 1993, p. 133). In this sense, the Michigan school takes independent dimensions (causes)[30], the Berkeley school with dependent dimensions (effects from the independent dimensions) as starting point for understanding the concept of high reliability.

3.2.1 The Berkeley HRO School

The University of California at Berkeley has become an international focal point for the progression of high-reliability theory (Smart et al., 2003, p. 736). The roots of this school are in the research of Morone and Woodhouse (1986) and Wildavsky (1988). It was on their work that the school's *founders* – Karlene Roberts, Todd La Porte and Gene Rochlin (and by extension Paul Schulman and Paula Consolini) have built to bring HRT to full growth. Their research employs a number of methodologies (Roberts & Rousseau, 1989) and bears a number of characteristics that make up the originality of its contribution.

In part thanks to their different background, Todd R. La Porte (political science), Karlene H. Roberts (psychology) and Gene I. Rochlin (physics - energy and resources) have made an important contribution to the way organizations are studied. What these scholars have in common and what differentiated them from their predecessors (and to a certain extent NAT) is the organizational perspective to organizational reliability. More particularly the merit lies in the combinatorial power of the elements they take into account to explain organizational reliability and in making these combinations and their effects explicit. The elements in themselves – the measures listed as Berkeley HRO apparatus – are part of well-studied organization theory, for instance from human resources management. For example, the Berkeley school relies on constructs like employee involvement, job rotation, regular sharing of information, and training, to name just these.[31] The three organizations studied in the initial phase of the project were the Federal Aviation Administration's Air Traffic Control System; Pacific Gas and Electric Company's nuclear power plant at Diabolo Canyon, California; and the US Navy's nuclear powered aircraft carriers (Roberts, 1993, p. 2). Cornerstones in the examination of high reliability in work by Berkeley students are (Pidgeon, 1997, p. 8):

1. an occupational danger culture (relating to personal relationships and their relation to self-protection from harm);
2. a task/security culture (operations through norms of perfectionism and critique of information); and
3. in times of crisis, typified by a pattern of decentralized decision-making and flexibility of response.

Their work greatly acknowledged the dynamic nature of/resulting from organizational culture and in that sense opposes the critique expressed by NAT (Perrow, 1999;Sagan, 1993) that high reliability cannot be achieved in organizations that are simultaneously interactively complex and tightly-coupled. It is beyond the scope of this dissertation to provide a full coverage of the Berkeley line of thought and to particularly address the constructs employed within the context of the Berkeley research group in the early years of HRT. We refer the interested reader to the literature to that effect (e.g. La Porte & Rochlin, 1994;La Porte, 1996;La Porte & Consolini, 1991;Roberts, Rousseau, & La Porte, 1994;Rochlin et al., 1987).

3.2.2 The Michigan HRO School

The Michigan school largely extended on Karl Weick's notions of SenseMaking (Weick, 1995) which are discussed at fuller length below. In its turn, SenseMaking is the emanation of theorizing on

Loosely Coupled systems (Weick, 1976;Orton & Weick, 1990), which again finds its origin in the Social Psychology of Organizing (Weick, 1979). Michigan students of high reliability organizations emphasize "*the importance of various people in the organization correctly perceiving the events before them and artfully tying them together to produce a 'big picture' that includes processes through which error is avoided*" (Roberts, 2003). Their major contribution is a paper by Weick, Sutcliffe and Obstfeld from 1999 (Weick et al., 1999) that has lead HRO research since because it has introduced/made explicit the notions of Mindfulness and Resilience (Weick et al., 1999). Because of their high face-validity, these notions have been capable of introducing the reliability theme with practitioners, as has become manifest with the publication of *Managing the Unexpected* (Weick & Sutcliffe, 2001). This book has the merit of revitalizing the discipline at the end of the last, and the beginning of this century and of offering it a jargon and structural framework. It is our belief that the Berkeley group, as founding fathers of the HRO got bypassed by that other group of HRO scholars at the Michigan State University because the ingredients offered by the former were not novel enough, whereas with their concept of mindfulness and resilience, the latter offered a much more appealing body of theory.

The central theme in the Michigan scholarship on high reliability is that HROs are so reliable because they have a certain state of 'mindfulness' (Weick & Sutcliffe, 2001 p 42). According to Weick et al. (1999), mindfulness is less about decision-making, which is the traditional focus of organizational theory and accident prevention, and more about inquiry and interpretation grounded in capabilities for action. HROs possess five key qualities to reach their state of mindfulness (Weick et al., 1999). These qualities enable HROs to compensate for their inherent tight coupling with attributes that loosen their coupling, hence contributing to a balance between efficiency and reliability. Through their Preoccupation with Failure, reluctance to accept simplifications, and Sensitivity to Operations, HROs are able to anticipate and become aware of dangers. HROs are able to contain dangers when they are spotted because they are committed to resilience and deferred to expertise.

The term Mindfulness was coined by Langer[32] (Weick et al., 1999, p. 88) and stands for "*[T]he combination of ongoing scrutiny of existing expectations, continuous refinement and differentiation of expectations based on newer experiences, willingness and capability to invent new expectations that make sense of unprecedented events, a more nuanced appreciation of context and ways to deal with it, and identification of new dimensions of context that improve foresight and current functioning. Mindfulness is a pre-occupation with updating. Mindful people accept the reality of ignorance and work hard to smoke it out, knowing that each new answer uncovers a host of new questions. Mindfulness is exhibited by high reliability organizations through the following five hallmarks of reliability: (1) Preoccupation with Failure, (2) Reluctance to Simplify interpretations, (3) Sensitivity to Operations, (4) Commitment to Resilience, and (5) Deference to Expertise*"(Weick & Sutcliffe, 2001, p. 10 & 42-44). Note, in line with Vogus and Welbourne, that when we refer to mindfulness, we are referring to it at the system or organization level (i.e. collective mindfulness) contrary to Langer's work on mindfulness (1989, 1997) which was derived from work on individuals (Vogus & Welbourne, 2003a, p. 880), stemming from psychology literature (Levinthal & Rerup, 2006, p. 502).

The three core HRO properties of Mindfulness, namely Preoccupation with Failure, Reluctance to Simplify, and Sensitivity to Operations, are dealt with next.

Preoccupation with Failure

Preoccupation with Failure is an important principle that gives HROs a distinctive quality, as this means that HROs are preoccupied with something they seldom see. Although HROs are successful in avoiding incidents, they do not boast about their superiority. HROs are wary for the common failures, caused by restricted search, reduced attention, inertia, risk aversion, and homogeneity. They treat even the smallest error as a sign that something could be wrong with the system. HROs regard narrow escapes as a kind of failure that reveals danger, and not, as most other organizations would do, as evidence of success and their ability to avoid accidents. Members of HROs know that they cannot foresee everything: they know that they do not know, and they expect to be surprised. That is why members of HROs are constantly worried that they make analytical errors and that these errors might be amplified, in combination with limitations to foresight, and lead to accidents (Muhren, Van Den Eede, & Van de Walle, 2007).

Acting from an assumption that the organization knows enough may represent hubris at best and bad management at worst (Zack, 1999). Avoidance of hubris is essential in achieving long-term reliability, because constant awareness of the possibility of failure is a precondition for avoiding it. Or as Weick and Sutcliffe put it: "*Arrogance and hubris breed vulnerability*" (Weick & Sutcliffe, 2001, p. 9). On the other hand, a well-established culture of safety and reliability might still result in overconfidence and hubris, which is then again the harbinger of calamity. Therefore, HROs put great emphasis on a culture that takes even the smallest error serious. In this they strongly differ from non-HROs because they give strong responses to weak signals (Weick & Sutcliffe, 2001, p. 3-4). The reason for this is twofold: firstly, avoidance of hubris by forcing organization members to remain alert and secondly, seizing every opportunity to learn from error. Such a culture of resilience (Weick & Sutcliffe, 2001) is built on strong norms, all-levels management commitment (Weick, 2001c), willingness and the competence to exchange information (Alavi & Leidner, 2001). "*If managers refuse to examine what happens between heads, they'll be eternally puzzled by what appears to happen inside individual heads*" (Weick & Sutcliffe, 2001, p. 13-14).

A culture of reliability and avoidance of hubris can be obtained in numerous ways. Grabowski and Roberts (1997;1999) name some: clear norms in the system about the relationship between failure and learning, secret ballots about volatile or sensitive issues, anonymous reporting of near misses in safety critical systems, use of brainstorming where the evaluation of ideas is suspended, a penalty box where people who commit glaring errors in the system are put for a finite period of time, after which they rejoin the action. Weick and Sutcliffe point out that the so-called 'big picture'[33] in HROs is less strategic and more situational than is true of most other organizations (Weick & Sutcliffe, 2001, p. 13). Culture provides a useful portmanteau concept which bundles up the '*baggage*' people bring to action: the different values, beliefs, norms, frames, and cognitive structures which influence sense making, filter information, and mediate the construction of organizational meaning (Intosh-Murray & Choo, 2002, p. 239). Despite these apparent advantages, culture poses a double dilemma though. A first dilemma, is that on the one hand, a strong culture is better for reliability in times of stability but on the other hand, a weaker culture is better suited to deal with change (Denrell, 2003, p. 237). The second dilemma is that strong cultures are more difficult to alter than weak cultures. The reason might be that success breeds confidence and fantasy (Starbuck & Milliken, 1988, p. 329-330). This reminds of the 'boiling frog syndrome' (Starbuck & Milliken, 1988, p. 337) that states that a frog can be boiled alive if the water is heated slowly enough. It is said that if a frog is placed in boiling water, it will jump out, but if it is placed in cold water that is slowly heated, it will never jump out. This story refers to the phenomenon of 'creeping normalcy' which means that if organizations – and in particular their management – do not learn to look out for continuous change.

These are all expressions of hubris. A good example is provided by Dörner (1996) in his monograph on the logic of failure where he reports on the Chernobyl disaster: "*The Ukrainian reactor operators were an experienced team of highly respected experts who had just won an award for keeping their reactor on the grid for long periods of uninterrupted service. The great self-confidence of this team was doubtless a contributing factor in the accident. They were no longer operating the reactor analytically but rather 'intuitively'. They thought they knew what they were dealing with, and they probably also thought themselves beyond the 'ridiculous' safety rules devised for tyro reactor operators, not for a team of experienced professionals*" (Dörner, 1996, p. 33). When a group exerts this kind of thinking on the group it conflict is minimized, but at the expense of critically testing, analyzing, and evaluating situations. During such groupthink (Janis, 1982b) the organization is vulnerable to risk.

Reluctance to Simplify

Because HROs believe that the world they face is complex, unstable, unknowable, and unpredictable, they try to notice as much as possible. Simplifications produce blind spots, so HROs differentiate in order to get a more varied picture of potential consequences and in turn, a richer and more varied set of precautions and early warning signals. HROs make fewer assumptions, cultivate requisite variety and socialize people to notice more. The law of requisite variety was originally proposed by Ashby (1962), and suggests that the larger the variety of actions available to a system, the larger the variety of perturbations in its environment it can compensate. HROs stimulate frequent job rotation and hire employees with non-typical prior experience. By these means, HROs obtain a broader divergence of perspectives, which leads to a broader set of assumptions that sensitize it to a greater variety of inputs. Although diverse groups have more information available than more homogeneous groups, communication patterns and cognitive limitations often lead to a situation where unique information does not get shared (Muhren et al., 2007).

Sensitivity to Operations

Because of the often-devastating physical or socio-economical consequences, HROs are forced to learn from even the smallest errors they make. During the incubation period of errors, it is important to look for inconsistencies – like incidents and accidents – that are the harbinger of a much greater risk. Unless the organization has an attitude of detecting these often insignificant events, these occurrences will be overlooked or misinterpreted (Grabowski & Roberts, 1997). The consequence is that when this 'preventative opportunity' (Berniker & Wolf, 2001, p. 10) is not seized, continued reliable operations are not assured. Therefore, HROs try to signal errors when they are still tractable and can still be isolated by attaining well-developed situational awareness. Situational awareness is defined by Endsley (1997) as "*the perception of the elements in the environment within a volume of time and space; the comprehension of their meaning and the projection of their status in the near future*". HROs consistently communicate the big picture of what the organization seeks to do, and try to get everyone to communicate with each other about how they fit in the big picture (Roberts & Bea, 2001a). With a situational awareness and a big picture, people in HROs can make continuous adjustments that prevent errors from accumulating and enlarging. Such Sensitivity to Operations is achieved through a combination of shared mental representations, collective story building, situation assessing with continual updates, knowledge of physical interconnections and parameters of the organization's systems, and active diagnosis of the limitations of preplanned procedures. Organizational awareness is enhanced by the extent to which members of an organization collectively become skilful perceivers of the business environment (Tsoukas & Shepherd, 2004). "*For an organization to sharpen its collective capacity to perceive is more difficult than for individuals. The reason is that organizing is the process of generating recurrent behaviors, namely a process for reducing differences among individuals through institutionalized cognitive representations. This is what gives organized systems predictability and efficiency; but this is also what gives them rigidity and crudeness. Organizing induces abstraction and generalization in social activities for coordinated purposeful action to become possible*" (Tsoukas & Shepherd, 2004, p. 6).

Commitment to Resilience

Resilience can be best described as: "*The process of being mindful of errors that have already occurred and correcting them before they worsen or cause more serious harm*" (Weick & Sutcliffe, 2001, p. 67). In this respect, the term is related to accident mitigation. "*Organizations committed to resilience develop knowledge and skills to cope with and respond to errors, capability for swift feedback and swift learning, speed and accuracy in communications, flexible role structures, quick size-ups, experiential variety, skills at re-combining existing response repertoires, and comfort with improvisation. Such organizations move decision-making rapidly to those with the necessary expertise*" (Weick & Sutcliffe, 2001, p. 67-68). Resilience is a tendency to return to a former equilibrium in the face of temporary perturbation or displacement (Longstaff, 2003, p. 16-17). If a complex system exhibits resilience it will bounce back from changes and is more likely to be stable in the long term. For this reason, Van Fenema (2005) labels resilience as some extraordinary 'elasticity'. Sutcliffe and Vogus (2003), on the other hand, address it as something 'ordinary' as they suggest that it emerges from relatively ordinary adaptive processes that promote competence, restore efficacy, and encourage growth. They posit that Threat Flexibility is essential in its emergence, namely when information and resources are plentifully available and control is not tightened in up-tempo times. In this their notion of Threat Flexibility is an alternative for threat rigidity (Staw, Sandelands, & Dutton, 1981).

Resilience is a combination of keeping errors small and improvising workarounds to keep the system functioning (Muhren et al., 2007). People in HROs are so committed to resilience, that they see this 'firefighting' as evidence that they are able to contain the unexpected. By contrast, managers in business may perceive successful firefighting as evidence that they are distracted and therefore unable to do their normal work (Weick & Sutcliffe, 2001, p. 70). HROs need to have a broad repertoire of actions they can roll-out when a danger occurs. HROs support improvisation to be able to recombine the actions in their repertoire into novel combinations. As Wildavsky (1988, p. 70) describes, "*improvement in overall capability, i.e. a generalized capacity to investigate, to learn, and to act, without knowing in advance what one will be called to act upon, is a vital protection against unexpected hazards*". Informal networks are a common resource for HROs to respond to dangers resiliently, because they provide an infrastructure that is needed to handle unanticipated dangers in a swiftly manner. When events get outside of normal operational boundaries, knowledgeable people organize themselves into ad hoc networks to provide expert problem solving.

Deference to Expertise

What people in HROs have mastered is the ability to alter typical hierarchical patterns of deference when the tempo of operations changes and unexpected problems arise. People who have the most expertise, regardless of their rank, then make decisions on the front line. In these situations, expertise and experience are usually more important than rank, so the decision structure in HROs is a hybrid of hierarchy and specialization. Decision-making authority therefore is shifted down to the lowest possible levels and clear lines of responsibility need to be called into existence (Ericksen & Dyer, 2005, p. 29). This way, the shift to anarchy is a controlled one, and comes from a collective, cultural belief that the necessary capabilities lie somewhere in the system and that migrating problems will find them (Muhren et al., 2007).

This argument has been further developed in Bigley and Roberts' (2001) study of an incident command system (ICS). "*An ICS is highly formalized, characterized by an extensive storehouse of rules, procedures, policies, and instructions. Jobs within the system are specialized and require particular training. Although highly bureaucratic, the ICS is also very flexible, because it is able to rapidly recombine people, resources, and structures to deal with unexpected situations. For example, the ICS is designed to 'oscillate effectively between various preplanned solutions to the more predictable aspects of a disaster circumstance and improvised approaches for the unforeseen and novel complications that often arise in such situations*" (Bigley & Roberts, 2001, p. 1282).

3.3 HRO Research

The literature on HROs is on organizations that behave "*under very trying conditions*" (La Porte & Rochlin, 1994, p. 221), thus the data base available to us for analysis, consists of an eclectic mix of case studies involving effective action […], limited failure […], near catastrophes […], catastrophic failures […] and successes that should have been failures […] (Weick et al., 1999, p. 83). This eclectic mix of publications has two consequences:

1. The ingredients that compose high reliability are always the same but they tend to be represented slightly differently. In what follows, we provide an overview of these representations. The reader will notice the overlapping of these characterizations. We have not been able to avoid this, since it is inherently part of the eclectic mix of studies in HRO literature.
2. Whereas these publications are an indication of the popularity and broad applicability of HRT, one can notice the emergence of what one could call *false* HROs. The fact that HRT has gained interest among managers, leads to the danger that this interest and mainstreaming of what it stands for is going to be to its own detriment. It is good Public Relations to be labeled 'HRO' independent from the fact that one really is HRO or is just paying lip service to its principles. The following illustrates what we mean: "*The employees said the company was preoccupied with safety slogans, such as the recently created 'Pantex High Reliability Organization', that were masking the stresses in the plant. Senior management is distracted, losing sight of the overall picture and circumstances," the letter said, adding that some managers lacked specific experience in handling nuclear weapons*" (Vartabedian, 2006).

Recall that in this study we do not wish to research High Reliability Seeking Organizations (HRSO) in the way they have been described by Vogus and Welbourne (2003a). HRSOs focus on innovation, adaptability to competition, decrease of response times and the like. Their focus is on efficiency. The HROs in our study have the containment of operational risk as their bottom-line.

For our study of literature on HRO, we have reviewed n=192 publications, ranging from journal articles, over conference proceedings, scientific reports to more popular contributions in professional magazines over a 20-year period ranging from 1987 to June 2008 (with two outliers from 1982 because they are considered the trigger for what would later become HRT and NAT). The objective of this overview is not exhaustiveness, but to give a fair idea of the wide range of publications in the field of HRO and its evolution over time.

The spread in publications is shown in Figure 2.2. Note that for reasons of comparison we have extrapolated the figure for the first semester of 2008. We notice the modest start of HRO scholarship end of the eighties, beginning of the nineties, followed by a short dip (to practically no publications) in 1991-1992, to see the publication output expand in 1993. The reason could be that the publication of New Challenges (edited by Roberts) and the Limits of Safety (Sagan) has triggered this sudden increase. The period following that, although showing a rate higher than prior years, witnessed a steady decline in the number of publications. This regression reached a minimum in 1998. From 1999 onwards, the trend is up. We believe the trigger for this evolution can be found in the publication of Weick, Sutcliffe and Obstfeld's (Weick et al., 1999) seminal paper in that same year. This trend seems to have reached a temporary plateau with as much as some 20 publications per year.

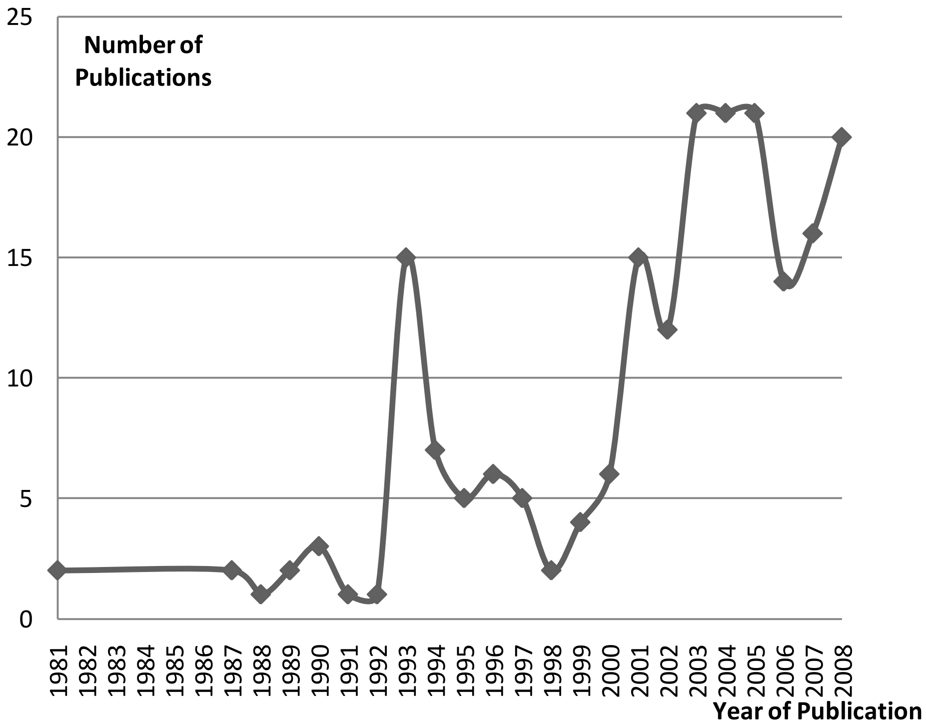

Figure 2.2 - Spread of HRO publications (1981-2008)

The most prominent researchers in the HRO field, responsible for one third of the publications in our study, are listed in Table 2.2. It can be noticed that the most productive HRO author by far is Karlene Roberts, followed by Karl Weick, Gene Rochlin, Todd La Porte and Paul Schulman (joint).

Author	*No. Publications*	*Share*	*Cum. %*
Roberts,K.	22	11%	11%
Weick,K.	8	4%	16%
La Porte,T.	7	4%	19%
Rochlin,G.	7	4%	23%
Schulman,P.	7	4%	27%
Gaba,D.M.	6	3%	30%
Roe,E.	6	3%	33%

Table 2.2 - HRO authors

We have catalogued the publications in our study along 8 dimensions: (1) the sector they apply to (e.g. health care, industry, military); (2) their focus on safety and/or reliability; (3) the organizational process (Design & Development, Information Technology, security, Human Resources Management, Incident Management); (4) the management activity (Strategic management, Crisis management, Project management, Command and Control, Decision making, Planning and Risk management; (5) the management paradigm (Knowledge Management, Organizational Learning, Change Management, Total Quality Management, Intercultural Management); (6) the research method (Qualitative, Quantitative); (7) the explicit common ground with other theoretical frameworks (SenseMaking and Normal Accidents Theory); (8) the nature of the publication (research paper, conceptual paper, paper on theory building, or a popular paper).

We can see from Table 2.3 that Health Care is the sector that gets most of the publications. This is a phenomenon especially from recent years (Figure 2.3). Nuclear energy, the military, aviation and firefighting, being much more traditional HRO sectors, count for much less, although taken together these five sectors account for 2/3 of total HRO publications (Table 2.3). It is clear that the interest from the Health care sector for the application of HRT is what has helped the theory survive.

Sector	*No. Publ.*	*%*	*Cumulative %*
Health care	42	26%	26%
NPP	25	15%	41%
Military	20	12%	53%
Aviation	12	7%	61%

Fire	8	5%	66%
Industry	6	4%	69%
Bank	6	4%	73%
Space	5	3%	76%
Marine	5	3%	79%
Railways	5	3%	82%
Electricity Grid	4	2%	85%
IT firm	4	2%	87%
Education	4	2%	90%
Manufacturing	3	2%	91%
Telecommunication	2	1%	93%
Prison	2	1%	94%
Humanitarian relief	2	1%	95%
Off-shore	2	1%	96%
e-government	1	1%	97%
Water supply	1	1%	98%
Science	1	1%	98%
Architecture	1	1%	99%
Pastoralism	1	1%	99%
Drug rehabilitation center	1	1%	100%
Total:	163		

Table 2.3 - HRO publications by sector

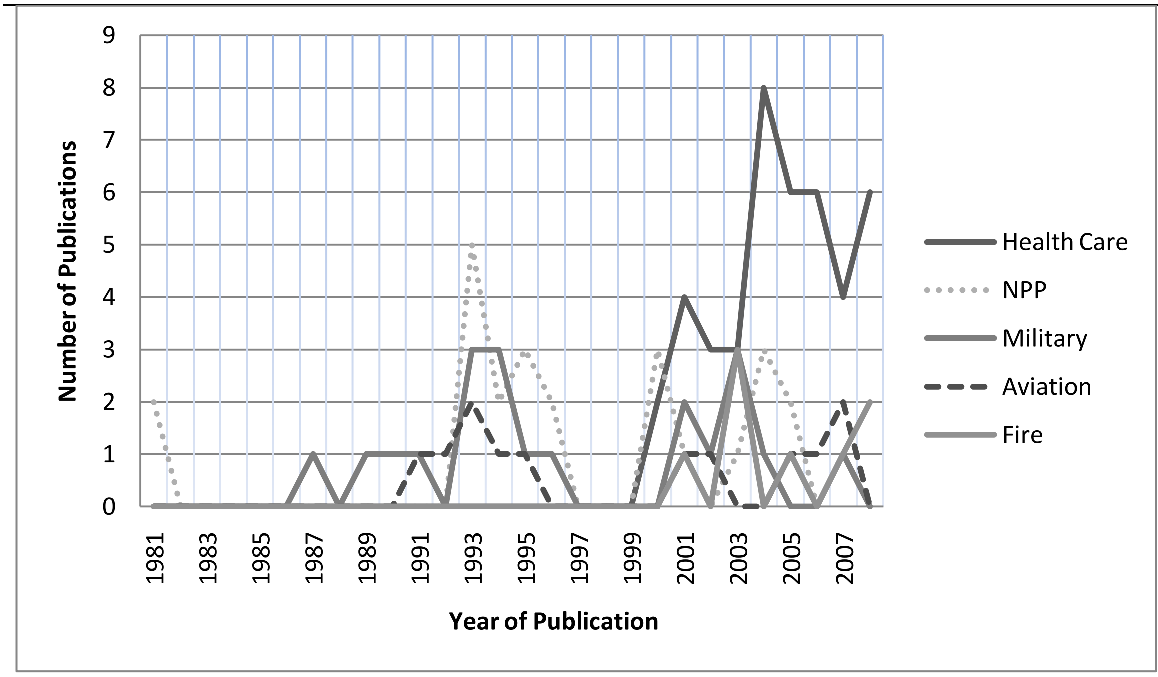

Figure 2.3 - Top 5 HRO Publications

Recent published data on healthcare organizations and high reliability have largely addressed either recommendations for improving reliability in individual hospitals' units that are at high risk of patient safety errors, or case studies of HRO principles (Dixon & Shofer, 2006). Again, applied at the clinical unit level, such as perinatal units (Frankel, Leonard, & Denham, 2006), operating rooms (Leonard, Graham, & Bonacum, 2004), and intensive care units (Pronovost, Berenholtz, Goeschel, Needham, Sexton, Thompson, Lubomski, Marsteller, Makary, & Hunt, 2006). The bulk of HRO writings are on safety, not on reliability (Table 2.4).

Safety/Reliability	*No. Publ.*	*%*	*Cumulative*
Safety	113	70%	70%
Reliability	49	30%	100%

Table 2.4 - Safety vs. Reliability

Business Process	*No. Publ.*	*%*	*Cumulative*
IT	13	50%	50%
Design & Development	4	15%	65%
Security	3	12%	77%
HRM	3	12%	88%
Incident Management	3	12%	100%

Table 2.5 - Business Process and HRO

From Table 2.5 can be derived that, as far as the business processes are concerned, publications seem to attach a great deal of attention to IT (50%). More remarkable is that only for 26 publications we have been capable of determining applicability to one or other business process. This definitely is a shortcoming of this body of literature as a whole. As is shown in Table 2.6, the majority of HRO literature deals with management activities that are characterized by time-criticality: decision making, risk management, crisis management and command and control issues constitute 85% of publications.

Management Activity	*No. Publ.*	*%*	*Cumulative*
Decision making	8	30%	30%
Risk	7	26%	56%
Crisis management	5	19%	74%
Command and Control	3	11%	85%
Project management	2	7%	93%
Planning	1	4%	96%
Strategic management	1	4%	100%

Table 2.6 - Management Activities addressd by HRO literature

From Table 2.7 can be derived that most HRT research in our survey of literature applies qualitative research techniques.

Research method	*No. Publ.*	*%*	*Cumulative*
Qualitative	45	63%	63%
Quantitative	27	38%	100%

Table 2.7 - Research methods addressed by HRO literature

4 Contrasting NAT and HRT

HROs operate in a setting of complexity and tight coupling. Unlike what is suggested by NAT, these organizations continue their track-record of success by accepting the fact that they "*cannot predict everything and set up systems that alert them to small changes so that they can prevent these small changes from becoming big problems*" (Longstaff, 2003, p. 19). It is their way of dealing with complexity.

For sake of clarity: we do not intend to favor either of the two theories over the other. Both have their merits, both have their tenuousness, both have potential. For this reason we agree with Rijpma (1997a, p. 22).to use insights from both to come to a framework integrating aspects of both frames of reference:"*Therefore, it can be concluded that NAT and HRT may gain much from cross-fertilization. Not only may theoretical discourse be enriched, but cross-fertilization is also important* *to provide practitioners with more comprehensive and balanced answers to strategic questions pertaining to accident prevention and reliability*".

Our starting point and foundation however, is HRT. The reasons are:

- HRT allows for the study of organizations that have not failed, which leads to a set of constructs with a broader applicability than NAT.
- HRT considers a broader set of constructs, originating from organization design, decision-making theory, organizational behavior etc., which ensures a richer palette to start from for drawing a reliable organization.
- HRT constructs are more easily measurable than the NAT dimensions of complexity and tight coupling.

Table 2.8 summarizes the competing perspectives on reliability, from a HRT and NAT perspective respectively.

HRT	*NAT*
Accidents can be prevented through good organizational design and management	Accidents are inevitable in complex and tightly coupled systems
Safety is the priority organizational objective	Safety is one of a number of competing objectives
Redundancy enhances safety duplication and overlap can make a reliable system out of unreliable parts	Redundancy often causes accidents: it increases interactive complexity and opaqueness and encourages risk-taking.
Decentralized decision making is needed to permit prompt and flexible field-level responses to surprises	Organizational contradiction: decentralization is needed for complexity but centralization is needed for tightly coupled systems.
A culture of reliability will enhance safety by encouraging uniform and appropriate responses by field-level operators.	A military model of intense discipline, socialization and isolation is incompatible with democratic value.
Continuous operations, training and simulations can create and maintain high-reliability operations	Organizations cannot train for unimagined, highly dangerous, or politically unpalatable operations.
Trial and error learning from accidents can be effective and can be supplemented by anticipation and simulations.	Denial of responsibility, faulty reporting and reconstruction of history cripple learning efforts.

Table 2.8 - Competing perspectives on Safety - Modified from Sagan (1993, p. 46)

Roberts (1990a, p. 111) makes this more specific, by presenting an answer to the challenges set by NAT. She has enumerated some of the dysfunctional characteristics in hazardous organizations and has formulated some responses to lessen their effect.

Characteristics of Complexity	Responses
- Potential for unexpected consequences	- Continuous training - Redundancy
- Complex technologies	- Continuous training - Responsibility and accountability at all levels
- Potential for systems serving incompatible functions to interact	- Job design strategies to keep functions separate - Training
- Indirect information sources	- Many direct information sources
- Baffling interactions	- Training of specialized language - Flexible exercises

Characteristics of Tight Coupling	Responses
- Time dependent processes	- Redundancy
- Invariant sequences of operations	- Job specialization - System flexibility - Hierarchical differentiations
- Only one way to reach goal	- Redundancy - System flexibility
- Little slack	- Bargaining and negotiation - System flexibility

Much can be learnt from the mutual criticism and self-criticism of both schools of thought. As we have stated in the introduction to this section, HRT and NAT have since long been described as opposing in that sense that they represent an optimistic and pessimistic view respectively. Not in the least, this duality has been reinforced by the publication of Sagan’s The Limits of Safety, a frontal attack at the address of HRT. Consequently this book has triggered a strong and well-elaborated response from HRO founding fathers, especially La Porte and Rochlin (La Porte & Rochlin, 1994;La Porte, 1994), a response upon which Sagan (2003) in his turn ardently responded to. Nevertheless, this categorization does not seem to be fruitful because of several reasons, the most important being that the scholars (from both sides) themselves do not seem to be satisfied with it.

4.1 Critique from HRT on NAT

4.1.1 Misreading

HRT scholarship reproaches their NAT counterparts (namely Perrow and Sagan) to have misread their work and intentions (La Porte & Rochlin, 1994, p. 221). Working from secondary analysis of organizational structure, behavior and culture, NAT seeks to estimate from them the relative likelihood of serious accidents. Then they go on to attribute to these organizations properties that they claim are representative of HROs, and then infer that the Berkeley group would have drawn contradictory conclusions (p. 221).

4.1.2 Static and univocal

"*Most organizations are not frozen into one of the four combinations that are possible in Perrow's 2*2 of loose/tight coupling and linear/complex interaction. Instead, whole organizations change character in response to changed demands, some proportions of any organization fit all four combinations, and all organizations, because of interconnected technologies and interconnected resource demands, are moving toward an interactively complex tightly coupled state*" (Weick et al., 1999, p. 85). NAT's static and univocal view on organizations is not realistic. Organizations change continuously because they are made out of people and together with this continuous change also their degree of coupling changes.

4.1.3 Unfalsifiable

Another critique is that Perrow's theory is unfalsifiable (Schulman, 2001). Indeed, an organization will always remain as reliable as '*the first catastrophic failure that still lies ahead, not the many successful operations that lie behind*' (Schulman, 2001, p. 346).

4.1.4 Defeatism

Cooke and Rohleder argue that although accidents may be 'normal' – in the sense that '*accidents happen*' – disaster is not an inevitable consequence of complex socio-technical systems (Cooke & Rohleder, 2006): "*Since incidents of varying severity are normal, a system must be put in place to control the frequency and severity of these incidents. Without such a system the incident rate and severity will not be controlled and only then is a disaster predictable*". They came to this conclusion after the analysis of the Westray mine disaster (Cooke, 2003) where they found that "*the fatal explosion was not a spontaneous event, but a consequence of a chain of events or precursor incidents that could have been detected by an effective incident learning system*" (Cooke & Rohleder, 2006, p. 234).

A similar argument can be found in those NAT predictions that did not come through. For instance, while Sagan's empirical findings (1993) were quite embarrassing for HRO students (Rosa, 2005, p. 232), the same can be said on the Y2K non-event, announced by Perrow in the epilogue of the second edition of his seminal work on Normal Accidents (Perrow, 1999). Another example pointing in the same direction is provided by Berniker and Wolf (2001, p. 23), where they report an unexplainable success for three of the more complex oil refineries in the sample they have studied.[34]

4.2 Critique from NAT on HRT

Cooke and Rohleder (2006) summarize Sagan's (1993) analysis of high-reliability theory as a reduction to four essential elements for success: (1) high management priority on safety and reliability; (2) redundancy and backup for people and equipment; (3) decentralized organization with a strong culture and commitment to training; and (4) organizational learning through trial and error, supported by anticipation and simulation. This is the basis for NAT's critique on HRT.

4.2.1 Restricted organizational learning

Sagan argues that the organizational learning required for the success of high-reliability theory will be restricted because of (1) ambiguity about incident causation; (2) the politicized environments in which incident investigation takes place; (3) the human tendency to cover up mistakes; and (4) the secrecy both within and between competing organizations (Cooke & Rohleder, 2006, p. 216). This lack of scrutiny by HRO scholars has also been reported by Clarke (1993): "*How is it possible that two groups of scholars, looking at the same class of phenomena, so fundamentally disagree on what they see? I am not really sure how to answer this question. But it is clear that HRO theory does not accord critical scrutiny to official statements and records*". Even an unsuspected source like Weick (Weick et al., 1999, p. 85) reports the danger of cover-ups of accidents compromising trial and error learning and of its anticipation of complexity but its failure to stop it from escalating: "*Competing interests seldom align behind safety*" (1999, p. 85).

4.2.2 Cognitively impossible

Being an HRO is cognitively impossible. "*The evidence presented in validating NAT will show that with respect to complex systems, this is a cognitively impossible task*" (Berniker & Wolf, 2001). "*When issues get too complicated, people can't keep their minds on the subject. There is a strict limit to how many things we can keep in our conscious minds at any one time*" (Snowden, 2005, p. 24-25). Even La Porte and Consolini (1991) describe the HRO performance as very unusual, very hard to maintain and even theoretically unexplainable. "*Variations in organizational mindfulness stem, in part, from differentiated role structures […], but also from individuals' finite capacity for mindfulness. Every individual and organizational subunit cannot be mindful about all issues, and therefore the depth and breadth of what they are mindful of is likely to vary*". Most organizations are specialized. Specialization imposes the need to coordinate, and integrating divergent views requires ongoing efforts to keep the infrastructure from unraveling' (Levinthal & Rerup, 2006, p. 506). A similar conclusion has been drawn by Bigley and Roberts (2001, p. 1290) where they mention that "*[a]s a system becomes larger and more elaborate, fewer and fewer of its emergent properties are likely to be held in the mental model of any one individual*". As a result, evolving, discrepant, and disconnected representations can become more and more widely dispersed across the system in a short time period.

4.2.3 The Cost of mindfulness

HRT writers from the first generation[35] seem to take a rather simplified approach to mindfulness where its costs are concerned. The conclusion therefore is that the sky is the limit: more is better. Mindfulness comes at a cost though, cognitively and financially. The Michigan school (in later work) and writers of the second generation have started to pay attention to the undesirability of mindfulness in less dynamic contexts (Weick & Sutcliffe, 2001, p. 87-88) and the cognitive cost of mindfulness (Vogus & Welbourne, 2003a;Swanson & Ramiller, 2004;Rerup, 2005).

Thought-provoking and revelatory research by Levinthal and Rerup (2006) has laid the foundations for the integration of less mindful, routinized behavior with the mindfulness advocated by HRT. They draw the attention to the opportunity costs associated with mindfulness: "*the opportunity costs of forgoing the use of established procedures as well as the opportunity costs of forgone attention*" (Levinthal & Rerup, 2006, p. 504). Because mindfulness is costly and demanding, mindlessness is a valuable choice as well (Swanson & Ramiller, 2004, p. 566). The warning therefore is not to fire with a cannon at a mosquito, since vigilant attention may not always be necessary and may be a waste of resources. In view of this argument, research is needed to identify when, and under what conditions, collective mindfulness is most appropriate and valuable.

Research is also needed to investigate the relationship between collective mindfulness and overall productivity. Collective mindfulness requires a commitment to reliability, which can be costly (Roberts & Libuser, 1993;Weick et al., 1999;Sullivan & Beach, 2003). Indeed, being and becoming an HRO comes at a cost. Extensive training programs or the maintenance of volumes of detailed technical documentation for instance can be very costly (Sullivan & Beach, 2003). Therefore, not every organization can have the ambition to be an HRO. Other measures are less costly. "*Measures to improve the communication between an organization's management and its workers, and the empowerment of workers to make decisions in times of crisis*" (Sullivan & Beach, 2003) for instance are more easy and cheaper to implement.

4.2.4 Undesirable side effects

Several of the mechanisms suggested by HRT have unwanted effects elsewhere in the system:

- Redundancy makes the system more opaque and hence more opaque (Weick et al., 1999, p. 85).
- Centralized decision premises can induce blind spots (Weick et al., 1999, p. 85).
- Conceptual slack shatters a common perspective and spread confusion (Weick et al., 1999, p. 85)
- Collective mindfulness might relate to individual-level outcomes, such as stress and burnout. Ensuring a mindful organization requires heightened vigilance and pro-activity (Weick et al., 1999). It is possible that consistently operating at such a high level would lead to high levels of employee stress and even burnout" (Knight, 2004, p. 50-51).

4.3 Self-Criticism

HRT scholars acknowledge that HROs might have trouble to guarantee their high level of reliability in the long run (at the same time asking the question how long run reliability must be before one considers a system highly reliable). "*How long does a system need to avoid disaster for that avoidance to count as evidence against the hypothesis of vulnerability to normal accidents*" (Weick et al., 1999, p. 85). On the other hand, NAT scholar Perrow (Afterword of the 1999 edition of Normal Accidents, p. 372) writes: "*A contrast of error-avoiding and error-inducing systems permits an 'optimistic' element in what Sagan describes as a basically pessimistic theory. It shows that inevitable as normal accidents may be, their frequency can be significantly affected by the configuration of the system because that configuration can discourage, even in an error-inducing system the small errors that make the unanticipated interaction of errors possible. In my book I argued that the air transport system managed to reduce tight coupling enough to make collisions extremely rare. In this view, HRT and NAT are not incompatible, but can inform one another. It requires a detailed examination of system characteristics, in effect, a contingency theory of system accidents*".

4.4 Beyond contingency: thesis, antithesis and synthesis

The above analysis has shown that the classical distinction between NAT and HRT does not hold. Not only are there elements that seem to cast doubt on this divide, it is also the potential of both theories for academia and practice. Therefore, post-Sagan research on high reliability (e.g. Weick et al., 1999) has moved beyond the extreme positions of NAT vs. HRT. It has changed the way it looks at the notion of 'higher reliability'. Older literature tended to see high reliability as a defining characteristic rather than as a reliability variable. Some researchers (Bain, 1999;Rijpma, 1997a;Rijpma, 2003) have recast the debate between the NAT and HRT perspectives and suggests that they should be seen as `complementary, not competing, perspectives'. This is more prominent from the side of HRT scholarship (e.g. La Porte & Rochlin, 1994), then from the side of NAT (Afterword to the 1999 edition, Perrow, 1999), were the stance is much more offensive[36]. HRT acknowledges the importance of tight-coupling and complexity but although it reaches a different conclusion, it cannot really be considered the conceptual opposite of NAT. Jarman (2001, p. 101-102) introduces the concept of lower-level reliability organization (or LRO/LRT) as the opposite of HRO/HRT, rather than a NAT. From the NAT *side*, Heimann (2005, p. 115), although critical of high-reliability organization theory, recognizes it "*has hit on some key ideas in successfully managing risky technologies*". We agree with Smart et al. (2003, p. 737) in their argument that such views engage a more pluralist and post-modern perspective as a basis for organizational action, and halt the process by which HRT or NAT become entrenched as singular world views in the minds of managers. The conclusion of the overview of this mutual and self-criticism hence can be no other than that one needs to take a contingency approach to high reliability.

NAT is HRT's antithesis. It is its alternative thesis and the value of its contribution to the emergence of a reliability synthesis is due to the fact that it starts from failure, which is the strongest scientific basis possible (Schäfer, 1996, p. 30-31). HRT starts from success which is a much weaker scientific basis because it is not contributing to falsification. In what follows, we argue why HRT and NAT cannot explain organizational reliability. Also, why it cannot be explained independently from them.

1. Both schools take unreliability as their starting point, with failure as a dependent variable (La Porte & Rochlin, 1994). Both schools start from a static view on reliability. NAT univocally describes organizations in terms of interactive complexity and coupling, deriving from this status their proneness to failure; HRT univocally describes them in terms of their culture, structure, behavior, information processing etc. Although HRT seems to take into account the dynamic nature of these properties and their change over time and the interaction between structure and behavior (La Porte & Rochlin, 1994, p. 221), it does not make it transparent and practical.
2. Both schools start from organizations that are characterized by interactive complexity and tight coupling. They have collected little empirical data on organizations that do not fit this straitjacket. *More cases ceteris paribus*. The result of the HRO research approach to study cases of success and of failure, is that reliability is treated as a binary (success or failure) concept (Ericksen & Dyer, 2005, p. 9). However useful such an approach may be, the problem, according to Schulman (2001, p. 347-348) is that: "*In research on high reliability in organizations we are beset by the problem of many variables and few cases. How, without more failures, can we really be sure which of the many organizational features we see are in fact adding to reliability? If we do establish a connection between given features of an organization and its operational reliability, can we assume that these features are necessary, rather than merely sufficient? […] Finally, even if an organization has evolved features that are necessary to its reliability, can we be sure that its evolutionary adaptation is stable, that what adds reliability today will also work tomorrow under changes in the character of technology, the work force, or in the life cycle of the organization?*" In other words, too much reliance on single case studies leads to a danger because there are too many variables and too few cases.

Thus, from a contingency perspective, could it be possible to conclude that the advocates of HRT are pleased with NAT because it helps them to be themselves even more? From a certain point of view, NAT is an inclusion of HRT. Without NAT, no HRT. They need one another to form their identity. Another way of seeing NAT as an inclusion of HRT is that HRT takes the same principles (interactive complexity and tight coupling) as a starting point, but that they have developed the toolkit to use them to their advantage. This framework is related to the original optimistic/pessimistic division but consists of tools allowing for a more nuanced examination of the contingency. The study of this framework is the subject of the following section.

5 SenseMaking

In this section we examine the SenseMaking[37] notion because of its potential contribution to a beter understanding of what constitutes organizational reliability.[38] Whereas HRT seems to address structural and contextual dimensions that explain organization behavior, it does not offer a lens for better understanding decision making. Sensemaking fills that gap as it describes how people act upon what is happening and continuously make decisions in order to get grip of the situation. SenseMaking therefore is a valuable complement to HRT.

SenseMaking literally means making sense of things. Thomas, Clark and Gioia (1993, p. 240) describe SenseMaking as "*the reciprocal interaction of information seeking, meaning ascription, and action*". The central activities of SenseMaking are information seeking, processing, creating, and using (Thomas, Clark, & Gioia, 1993), meaning that SenseMaking is not a noun, but a verb; that it is a process, with sense as its product. It encompasses intuitions, opinions, hunches, effective responses, evaluations and questions (Savolainen, 1993). SenseMaking is the process of creating a mental model of a situation, particularly when this situation is ambiguous (Klein, Moon, & Hoffman, 2006). It is "*a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively*" (Klein et al., 2006, p. 71). In this respect, it is different from creativity, comprehension, curiosity, mental modeling, explanation, or situational awareness, although all these factors or phenomena can be involved in or related to SenseMaking. SenseMaking is a meta-cognitive framework that can be used to get a grip on the equivocal external environment and its openness to multiple interpretations. It addresses questions like: '*What is happening out there?*', '*Why is it taking place?*', '*What does it mean?*' (Klein et al., 2006, p. 5). Although not correct, we juxtapose SenseMaking and decision making, because in reality it could be argued that decision making is an inclusion of SenseMaking. However, for reasons of clarity, the remainder of this dissertation treats them as opposites. We do so because of the much broader perspective offered by SenseMaking opposed to the rationalistic and mechanistic characteristics of decision making (Boland, 2008).

Practically speaking, SenseMaking is a cognitive process (Boland & Yoo, 2003) that can be described through seven properties (Weick, 1995): Identity Constructing, Retrospective, Enacting, Social, Ongoing, Cue extracting, and Plausibility seeking (Table 2.9). It is the process by which individuals (or organizations) "*create an understanding so that they can act in a principled and informed manner*".

Identity Constructing. The organization seeks to discover what it 'thinks' and 'knows' about itself and its environment. Depending on who the Sensemaker is, the definition of what is happening will also change. What the situation means is defined by who one becomes while dealing with it or what and who one represents (Weick, 1995, p. 20).
Retrospective. SenseMaking is an examination of past practices in order to learn/unlearn things about the current context (Nathan, 2004).
Enacting. There is no objective environment out there separate from one's interpretation of it. "*People often don't know what the 'appropriate action' is until they take some action, guided by preconceptions, and see what happens. Action determines the situation: The product of action is an orderly, material, social construction that is subject to multiple interpretations*" (Weick, 1988).
Social. "*Other people are integral to our efforts to make sense of things because what we say or think or do is contingent on what others say and think and do. People learn about events when they compare what they see with what someone else sees and then negotiate some mutually acceptable version of what really happened*" (Weick, 1985).
Ongoing. SenseMaking takes place in a continuing and dynamic fashion as events unfold and we continually seek to understand what events mean in relationship to our organizations. SenseMaking has neither a beginning nor a formal end (Nathan, 2004).
Cue Extracting. We decide what to pay attention to.
Plausibility-driven. Looking for what is plausible is often of more practical help then finding accuracy.

Table 2.9 - SenseMaking properties (Weick, 1995)

In essence, the seven properties boil down to '*How can I know what I think till I see what I say*'. "*This recipe, which is central in organizational SenseMaking, retains several elements of dissonance theory. The recipe is about justification (my thoughts justify my earlier words), choice (I choose which words to focus on and which thoughts will explain them), retrospective SenseMaking (I look back at what I said earlier from a later point in time when the talking has stopped), discrepancies (I feel a need to see what I say when something doesn't make sense), social construction of justification (I invoke thoughts I have been socialized to label as acceptable), and action as the occasion for SenseMaking (my act of speaking starts the SenseMaking process)*" (Weick, 1995, p. 12). The best synthesis, however, is offered by Weick et al. (2005, p. 419) when they formulate a conclusion on what the seven SenseMaking properties are all about: "*Taken together these properties suggest that increased skill at SenseMaking should occur when people are socialized to make do, be resilient, treat constraints as self-imposed, strive for plausibility, keep showing up, use retrospect to get a sense of direction, and articulate descriptions that energize. These are micro-level actions. They are small actions. But they are small actions with large consequences*". They summarize SenseMaking's distinguishing features as a "*genesis in disruptive ambiguity, with beginnings in acts of noticing and bracketing, founded in a mixture of retrospect and prospect, characterized by a reliance on presumptions to guide action, embedded in interdependence and a culmination in articulation that shades into acting thinkingly*".

Research on SenseMaking has been taking place for many years and by a great number of scholars, but unarguably it has reached full growth under the inspiration of Brenda Dervin (e.g. 1983a) and Karl E. Weick (e.g. 1995). Although both scholars have taken a different line of approach to the topic and have been conducting their research independently from each other, their work definitely has a common denominator. For many years – and to a certain extent even today – the SenseMaking concept has remained undiscovered by mainstream literature but under the impulse of the Organizational Learning thought, it rightly got a broader interest by scholars in organization theory. This should not come as a surprise, since the process of improving action through better knowledge and understanding, is integrally connected to SenseMaking (Nathan, 2004). Organizational awareness is enhanced by the extent to which members of an organization collectively become skilful perceivers of the business environment (Tsoukas & Shepherd, 2004). The idea of SenseMaking has reached full growth under the inspiration of Karl E. Weick (2001). However, despite the increasing attention, it would not be wise to label SenseMaking a theory: "[…] *SenseMaking is best described as a developing set of ideas with explanatory possibilities, rather than as a body of knowledge*" (Weick, 1995, p. xi). This is in line with Dervin's depiction of SenseMaking: "*Some people call it a theory, others a set of methods, others a methodology, others a body of findings. In the most general sense, it is all of these. It is, first and foremost, a set of metatheoretic assumptions and propositions about the nature of information, the nature of human use of information, and the nature of human communicating*" (Savolainen, 1993, p. 16).

The classification between individual and organizational SenseMaking is artificial. Individual SenseMaking is senseless without the collective (i.e. social) dimension, "*making 'individual SenseMaking' something of an oxymoron*" (Weick, 1995, p. 80). We therefore will not explicitly make that distinction as we carry on with the elaboration of the SenseMaking construct. What is far more characterizing is that SenseMaking is all about coping with interruptions. "*To understand [S]ensemaking is also to understand how people cope with interruptions'* (Weick, 1995, p. 5). "*SenseMaking is tested to the extreme when people encounter an event whose occurrence is so implausible that they hesitate to report it for fear they will not be believed. In essence, these people think to themselves, it can't be, therefore, it isn't*" (Weick, 1995, p. 1). SenseMaking deals with omnipresent discontinuity in constantly changing situations. Dervin (e.g. Dervin, 1999) labeled this as '*gappiness*', meaning that people are constantly confronted with dissonance, ill-structured problems, ambiguity and equivocality.

If one were to name one setting where SenseMaking would be most relevant, it would be situations where the gappiness is the most evident. The handling of high priority incidents (high impact, high urgency) is such a setting. In such situations the observation is that discontinuity is the rule, continuity the exception, while usually management and systems are designed according to the exception (Turoff, Chumer, Van de Walle, & Xiang, 2004). If the dominant assumption is continuity, systems are designed to deal with flows, process alignment etc. They are not designed for dealing with the alternative assumption of discontinuity. The problem is that a system that is designed according to the worldview of continuity does not help in practice because it conflicts with the discontinuity of reality. We find ourselves always in the middle of a situation that needs being made sense of. The purpose of our action therefore is to overcome our *thrownness* (Heidegger, e.g. in Inwood, 1997), i.e. the ongoing experience and being in the middle of things.

6 Information Systems Fit

6.1 Introduction

This section deals with the issue of aligning (i.e. fitting) Information Systems, users and tasks. After an introduction of the problem statement and rationale behind IS Fit (6.1), we analyze the different components of user-system fit. In that respect we look into the position of information systems as such (6.2) and aspects related to the 'user' notion (6.3). Finally, we examine the role of fit (6.4).

6.1.1 Problem statement

An Information System is more than the hardware and the software. It is as much – or even more – the structure, procedures and people that make it work. We posit that the degree of flexibility that emerges from these system aspects is in essence determined by how the organization is coping with interruptions through its structural dimensions (Pugh et al., 1968;Pugh, 1973) – we have referred to this as *High Reliability Organizing* – and through its information processing capacities, referred to as *SenseMaking*. To guarantee the dynamics described in the previous sections of this literature review chapter, we believe that the design of Information Systems that are aimed at supporting organizational reliability hence should encourage and support a process of Mindfulness and SenseMaking. In practice however, it can be noticed that IS design does not support these High Reliability and SenseMaking modes. In fact, it does the opposite because it aims at replacing or suppressing the possibility to 'make sense' of situations. IS are conceived as a 'repository of best practice' model (Boland & Yoo, 2003, p. 390) which puts an emphasis on data storage, instead of on connecting people and stimulating reflection and building one's own story line. Likewise, IS are designed top-down, with an emphasis on rigidly following predefined and static procedures. The consequence thereof is that IS are not supportive of stability and flexibility and that organizational reliability is jeopardized.

It should be possible though to design IS in such a way that it combines both virtues (stability and flexibility), the sine qua non being that a dynamic one replaces the static approach. The key to such design is finding the right 'fit' or alignment between the different IS components. In this section we specifically address the consequences for the incident support tool and more particularly the way it is used in view of communication and coordination and the impact thereof on organizational reliability. We do not believe – as is argued by Bostrom and Heinen (1977, p. 18) that computer-related technology is essentially neutral and that whether its application succeeds or fails depends entirely on the decisions that are made on how it shall be used (i.e. procedures, training, etc.).[39] Therefore, the fit we are trying to define cannot be seen as a static notion, as a cookbook recipe, but as a framework that can guide IS designers, analysts and managers in their daily practice of making collaboration and coordination work. Such an interpretation of IS fit, with working practices and organizational structures, including those that moderate collaboration between individuals (Payne, 2003), now generally is acknowledged to be essential for the usefulness of a computer system.

6.1.2 Rationale

To account for the rationale of our writings in this section, we draw and juxtapose on Markus (1983) reporting three theories that have the potential of explaining why users resist to management information systems (MIS): (1) their own internal factors; (2) poor system design; (3) the interaction of specific system design features with aspects of the organizational context of system use. Important in Markus' work is that he acknowledges that these theories differ in their basic assumptions about systems, organizations, and resistance. Remarkable is Markus gathering of empirical evidence for the dominance of the interaction theory. Our study, however, demonstrates the importance of the interaction of all three theories. We do so by means of the conceptual model depicted in Figure 2.4.

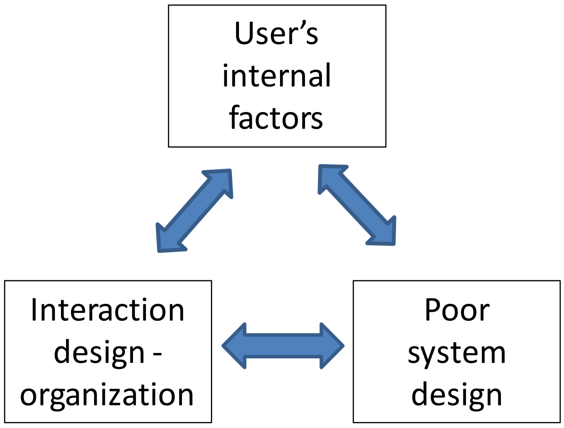

Figure 2.4 - IS Interaction Model

The originality of our contribution lies in the addition of SenseMaking and High Reliability constructs as lenses that offer the possibility of synthesizing the three presupposed theories. In all three of these classical theoretical streams, we add aspects of structure and agency. The application of this set of constructs is novel, because previous studies on the reliability of complex systems that also applied HRO constructs – for instance Carlo et al. (2004) – have approached HRO literature from an IT artifact perspective. By this, we mean that when HRO research deals with IT, it is merely in its role of increasing interactive complexity and tight coupling, not as a potential enabler of mindfulness. This section makes an original contribution to the Information Systems discipline, by addressing the link of high reliability theorizing and IS fit. We posit that it has the potential of offering a practical interpretation of what is meant by flexibility (and hence also stability). This fills a need, for two reasons: (1) the underdevelopment of Human Computer Interaction (HCI) in the field of coordination and (2) the under-specification of the flexibility notion. These issues are briefly dealt with next.

Underdevelopment of HCI in the field of co-ordination

Despite the general acknowledgement that systems are the aggregation of hardware, software, procedures and people, its translation into practice is less self-evident. Their design and implementation does not take into account the reciprocity that exists between them and moreover is static and therefore incapable of adjustment to contingency. Therefore it should not come as a surprise that much of the basic research into Human Computer Interaction (HCI) has not attempted to provide techniques to understand and help design for these situations, preferring to study and provide support for solitary and decontextualized activities (Perry, 2003, p. 193). Perry explains that – despite its tremendous importance – one of the reasons for this is that HCI theoreticians and modelers have not had a 'way into' the problem – cognitive theory tells us little about social behavior, while the social sciences' understandings and explanations of social action are hard to apply directly to design. How process members adapt and make use of tools in their work to support their cognitive abilities is poorly understood. This is because the theoretical approaches and experimental methods that have been applied to the area are not, in general, able to investigate these kinds of behavior (Perry, 2003, p. 193). Therefore (IS) designers need to have a better understanding of work that goes beyond the individual, to look at how teams coordinate their behaviors with one another, collaborate, and perform problem-solving tasks (Perry, 2003, p. 193). Finding out how system users coordinate their action in relation to the structural and contextual determinants they are guided by is the first objective of this section.

Under-specification of the flexibility notion

Most research does not define what is meant by 'flexibility': "*What should be flexible: the IT organization, the people, and the technology? How is flexibility developed, how is it managed?*" (Patten, 2004, p. 4). The question arises how flexibility is achieved. The position taken in this dissertation is that it cannot be embedded statically in the design of the system but that it is determined by the degrees of freedom system users have when accomplishing their tasks. These degrees of freedom in themselves again are bounded by limitations so that stability can be assured. How this is combination of stability and flexibility is guaranteed with respect to information systems (in the broadest sense) design (also in the broadest sense) is the second objective of this section and its underpinning by data (Chapter 6).

6.2 Information Systems (IS)

Information technology research (at least in general) acknowledges an IS as an actual system of physical, social and cognitive elements that are built, used and rebuilt by people in everyday practice (Griffith & Dougherty, 2001, p. 208). Despite this acknowledgement, everyday practice (and part of scientific research) sticks to a static IS notion. This shows itself mainly in the disregard towards two factors mainly: (1) user characteristics and (2) contingency, i.e. the indeterminacy of the context.

Several authors have dealt with this issue. Among them, Orlikowski (1992) who has reported several occasions where the combination of user characteristics and contingency has lead to users employing different strategies for using IS. "*Rather than positing design and use as disconnected moments or stages in a technology's lifecycle, the structurational model of technology posits artifacts as potentially modifiable throughout their existence*" (Orlikowski, 1992, p. 408). Such is also clearly shown in case of electronic mail by Mackay (1988), implying designers should seek flexible solutions that capture the important dimensions of use and provide flexibility for a wide range of users. Apart from the work by the authors mentioned above, at least in our view, it is Weick (1985) who has pinpointed the problem best: "*Representations in the electronic world can become chaotic for at least two reasons; The data in these representations are flawed, and the people who manage those flawed data have limited processing capacity. These two problems interact in a potentially deadly vicious circle. The data are flawed because they are incomplete; they contain only what can be collected and processed through machines. That excludes sensory information, feelings, intuitions, and context — all of which are necessary for an accurate perception of what is happening. Feelings, context, and sensory information are not soft-headed luxuries. They are ways of knowing that preserve properties of events not captured by machine-compatible information. To withhold these incompatible data is to handicap the observer. And therein lies the problem*" (Weick, 1985, p. 51-52).

For these reasons, the technology will be appropriated in diverse ways and has different meanings and effects for different users. The conclusion therefore is that humans may appear to act within the constraints of technology and institutions (Rose, 1999). The combined effect of differing user properties and indeterminacy means that information technology is not always used in ways envisioned by designers or intended by implementers (Orlikowski & Robey, 1991, p. 157). This combined effect at the same time means that "*Information technology does not simply determine behavior, but is actively invoked and appropriated by human actors*" (Orlikowski & Robey, 1991, p. 157). "*Examining selected relationships (e.g., studying how information technology influences users, without understanding how users appropriate the information technology, or the conditions within which the mediation occurs) can only result in a partial understanding of how information technology interacts with organizations*" (Orlikowski & Robey, 1991, p. 154).

The difficulty however, often is that most designers and engineers of such systems are comfortable identifying a problem and improving or fixing it. "*They prefer to deal with absolutes rather than probabilities, and do not consider the stochastic nature of these systems and their associated subsystems*" (Azadeh, 2000, p. 210). Designers and engineers tend to believe that reality can be modeled, but unfortunately, complex systems cannot be simplified and hence do not fit into a model. The reason is that due to the nonlinear nature of the interactions in a complex system, complexity is incomprehensible and therefore incompressible. This means that there is no accurate representation of the system that is simpler than the system itself (Cilliers, 2000, p. 9). In building representations of open systems, we are forced to leave things out, and since the effects of these omissions are nonlinear, we cannot predict their magnitude. This is not an argument claiming that reasonable representations should not be constructed, but rather one that the unavoidable limitations of the representations should be acknowledged (Cilliers, 2000, p. 9).

6.3 IS Users

The previous discussion has shown that user characteristics are essential in the way an Information System is used. What follows takes this discussion one step further by decomposing the notion of user characteristics. It does so by addressing cognitive profile (subsection 1), underlying worldview, assumptions and values (subsection 2), and the reverse designer perspective (subsection 3).

6.3.1 Cognitive profile

An individual's psychological attributes (i.e. cognitive profile) influence his/her decision making behavior (and information processing behavior) (MacCrimmon & Taylor, 1976, p. 1439):

1. Perceptual ability (The way in which a decision maker perceives a problem is a major determinant of the degree of uncertainty, complexity, and conflict. […] His perceptions depend upon the premises he holds about the decision situation.)
2. Information capacity with the distinction between abstractness and concreteness as a most important feature. Concreteness is characterized by the use of few dimensions of information and simple integrating schemata; Abstractness is the tendency to process many dimensions of information and to use complex integrative schemata.
3. Risk taking propensity
4. Aspiration level

6.3.2 Worldview, prior experiences, assumptions and values

Apart from the cognitive profile outlined above, each individual interprets and internalizes knowledge differently depending on personality traits, prior experiences, expectations (Storck & Henderson, 2003, p. 513) (referring to Weick (1995)) and worldview. A range of social and organizational factors are embodied in the values of various IS stakeholders (Tan & Hunter, 2002). Therefore, any explicit presentation of social and organizational factors is a discussion of people's underlying assumptions and values (Orlikowski & Gash, 1994). Values are the basis on which objectives can be created. As noted by Keeney (1992, p. 24), "*bringing . . . values to consciousness allows you to uncover hidden objectives, objectives you didn't realize you had*". Examples of these values are mental models and schemes. Dhillon and Torzadeh (2006, p. 295-296) report that although values have been considered important and various authors have used a variety of techniques to undertake their research, no specific methodology has taken hold. Our explicit formulation of what we understand as SenseMaking or High Reliability proneness therefore is a valuable candidate for labeling the values and assumptions underlying organizational behavior.

6.3.3 Systems designer's implicit theories

Independent from the worldview and cognitive profile of the user, it will be clear that a system – any system – will be designed according to one particular dominant worldview (or combinations thereof). In other words, the design will greatly depend on the designer's worldview as well. This means that the fit between the system user and the system is heavily depending on chance. The fact that still at so many occasions the fit is realized despite of this chance element is not surprising since the designers and users very often share the same worldview.[40] Nevertheless, systems designers clearly though implicitly make assumptions: (1) about people, e.g., 'people are poor information processors', (2) about organizations, e.g., 'information flow downward must be controlled', and (3) about the change process, e.g., 'we must get users to participate or they will not accept the system' (Bostrom & Heinen, 1977, p. 19-20). This corresponds to the Theory X, traditional or machine theory, and Theory Y, human resource theory. Theory X assumes a person is one who likes order, wishes to work within tightly specified boundaries, and does not want to have a great deal of personal control over one's activities. Theory Y assumes a person is a responsible, self achieving individual who can take full control of one's work environment (Bostrom & Heinen, 1977, p. 19-20).

6.4 IS Fit

This brings us to the topic of how fit is accomplished. Depending on the adherence to either theory X or theory Y, the way 'fit' is assured can differ substantially. The different approaches are dealt with next.

6.4.1 Task/System Fit (TSF)

If one is to consider how an incident handling tool (like Peregrine) is used – or not used – in view of process reliability, two theoretical concepts come to mind: Task/System Fit (TSF), also known as Task Technology Fit (TTF) (Goodhue & Thompson, 1995). The concept of task/system fit focuses on the alignment between capabilities or functionalities provided by a given information system and the information processing requirements of the task in which the system may be used (Nance, 2005). The idea behind this concept is that the better the fit, the better a task will be accomplished by a system user and therefore represents a contingency perspective on organizing (Goodhue & Thompson, 1995). As such, the quality of the task outcome is determined by the information processing requirements of a given task on the one hand and information processing functionalities in an information system on the other hand. This constitutes a mere 'objective' engineering perspective (Nance, 2005) on task/system fit. In that sense, it corresponds to Theory X (supra).

6.4.2 Congruent Fit

The view underlying the static IS design outlined above is built on a *resource based view* on organizing (Wernerfelt, 1984) and more particularly since the nineties on a *competence based* view (Hamel & Prahalad, 1994;Conner & Prahalad, 1996). This school of thought posits the importance of a focus on core elements. This evolution is at odds with a systems perspective on organizing (see e.g. Lawrence & Lorsch, 1967) and like it has been articulated by Galbraith (1973) as *congruent fit*. Porter (1996) formulates his critique on the resource based view and his plea in favor of congruent fit as follows: "*The importance of fit among functional policies is one of the oldest ideas in strategy. Gradually, however, it has been supplanted on the management agenda. Rather than seeing the company as a whole, managers have turned to 'core' competencies, 'critical' resources, and 'key' success factors. In fact, fit is far more central component of competitive advantage than most realize*". In the words of Starbuck and Nystrom: "*A well-designed organization is not a stable solution to achieve, but a developmental process to keep active*" (Starbuck & Nystrom, 1981, p. 14). In that respect, congruent fit is a far more powerful notion for driving stability and flexibility than the static image of fit propagated by static business alignment frameworks like TTF. In our research we explicitly want to include the cognitive information processing style and underlying worldview of the individual completing as a third component (Nance, 2005).

Our critique on TTF models – and herein lies the intended value of our contribution – is that contingency is overlooked in that sense that a one-dimensional perspective is taken towards TTF. The interaction between (1) task, (2) user characteristics and (3) system characteristics and capabilities remains underdeveloped and under-researched. The idea of a static notion of fit stems from a mechanistic worldview where context is stable and can be kept under control. Tasks and technology – like structure and strategy for that matter – can be aligned for an undetermined period, resulting in an optimal reliability. Adjustments to this fit are relatively infrequent and occur in a discrete way (as opposed to continuously) after a formal initiative and decision of system designers. The idea of a dynamic notion of fit finds its origin in systems- and complexity thinking where context is instable and the objective should not be to control it, but to go with it in order to yield the best (not the optimal) reliability achievable. Fit thus is continuously on the move. It cannot exclusively be caught in fixed procedures, best practices, structures and strategies. This kind of fit emerges from the day-to-day behavior of people trying to make sense out of the situations they run into. Therefore, adjustments to this fit are made incrementally and continuously. In that sense, the schism between the world of the system and the world of the organization can be bridged and combined changes can solve problems that any change on only one side (technology or organization) cannot resolve (Schwabe & Krcmar, 2000).

Also important in this respect is that we adhere to Dervin's (1983b) viewpoint that human use of information should be studied from the perspective of the actor, not the intermediating system, such as an incident management support tool. The mere system view looks at structural variables such as age, sex, education, team membership, life style, or task description (Savolainen, 1993, p. 19) and derives from this system characteristics that should be met. The user view starts from the given that that the user is the essential order, and the system bends to it rather than the other way around (Savolainen, 1993, p. 19).

Chapter 3 Research Methodology

If we knew what we were doing,
it wouldn't be called research, would it.
Albert Einstein

1 Introduction

To effectively study a topic as complex as the incident management process reliability, it is difficult relying on one single or two measurement tools only (Sullivan & Beach, 2002, p. 1424). Early in our research, we realized we were studying quite an extra-ordinary process – the Incident Management Process – for which existing theory did not appear to be useful, showed drawbacks or did not exist. The absence of a well-established body of literature forced us to dig as deep as possible into the tissue of the matter, in search of something to go by. This called for another approach than the a priori *royal* road to scientific research, for which one kind of data gathering would suffice. In literature on research methodology this approach is known as *triangulation* and can – in brief – be best described as a combination of several data gathering techniques (and of theory). Triangulation – by permitting multiple instances for interaction between theory and data – offers multiple perspectives. The deeper, science-philosophical foundation of this approach is hermeneutics, which is the thread throughout our research and which has proved to be a very useful guide.

This chapter describes the research methods and their science-philosophical foundations we have used throughout this dissertation. It shows why and how we triangulated between qualitative and quantitative research methods and – within these broad categories – between the different techniques. In that respect, the term 'research methodology' goes deeper than what is meant by 'research technique'. *Methodology* is the overall process guiding the entire research project; *technique* on the other hand, is the primary evidence generation mechanism (Palvia, Mao, Salam, & Soliman, 2003, p. 3). After a description of both our case studies (Section 2), we first elaborate on the conceptual and science-philosophical underpinning of our approach that has its roots in hermeneutics (Section 3). Next, we translate these remarks into HRO research taxonomies (Section 4). Subsequently, we describe the research build-up in more detail (Section 5). Special attention goes to the survey as our main data collection technique (Section 6). We conclude this methodology chapter with a build-up of the hermeneutic circle of understanding (Section 7).

2 HRO Case Studies

2.1 Bank Case[41]

This section and the next one provide an overview of the organizations at which this study has been conducted, the financial institution (hereafter referred to as the 'Bank') and the nuclear power plant (hereafter referred to as the 'NPP'). A nuclear power plant, any nuclear power plant for that matter, is an archetypical HRO, as discussed above. A financial institution is an archetype of a mainstream organization. However, we posit that the incident management process under study bears the hallmarks of an HRO. A part of our research wants to find out whether this assertion holds. Therefore, it is essential to have a description of the organizations under study in mind. Subsection 2.1 describes the Bank and the Incident Management Process whereas subsection 2.2 portrays the NPP and the Maintenance & Repair Process.

2.1.1 The company

The Bank under study is a large European financial services provider in the field of Banking and insurance. It has branches in 30 different countries and offers a full range of financial services to retail and corporate customers. It holds a key position in several European countries. The holding was created in the late nineties through the merger of two Banking groups and one insurance company and now serves some 12 million customers and employs about 50.000 people. It holds a Euro zone top-20 ranking in terms of market capitalization.

2.1.2 The IT department

The financial institution's centralized IT department employs over 2000 people and has a budget of on average 400 million euro. It has an IT Governance program in place consisting of (De Haes & Van Grembergen, 2005): clear structures (roles and responsibilities, IT organization structure, IT strategy committee, IT steering committees), well-defined processes (Strategic Information Systems Planning, Balanced (IT) scorecards, Information Economics, Service Level Agreements (SLAs), Control Objectives for Information and related Technology (COBIT) and Information Technology Infrastructure Library (ITIL), IT alignment, and governance maturity models), well-described relational mechanisms (e.g. account management roles, and an IT governance internal magazine and intranet (De Haes & Van Grembergen, 2006), active participation and collaboration between principle stakeholders, partnership rewards and incentives, business/IT co-location, cross-functional business/IT training and rotation). This research particularly addressed two (out of 27) IT processes that were deemed to be vital to the Bank's survival. The first process is a cross-border payment service that provides back-office processing services to financial institutions for all international payments. The second process is an integrated solution that enables businesses customers and a number of government departments to carry out all of their Banking transactions and allows document handling (e.g. signing contracts, sending and receiving invoices).

From this company and process description, we derive the resemblance with an HRO setting. The interactive complexity, tight coupling and high impact of failure make the Bank context comparable to an archetypical HRO like a NPP. The means and methods by which the organization ensures reliability – under continuous pressure to increase efficiency and decrease the potential for human error – are very costly in personal and economic terms. It can be argued that the handling of incidents in such a setting calls for working under particularly demanding conditions as nearly all critical business processes are relying on their services for their reliability.

2.1.3 The Incident management process

The IT incident management process bears considerable resemblance with any incident management process, be it the IM of a mainstream organization or an emergency/high hazard organization (Wolf, 2004). The process is described in detail next.

IT Service Management and Information Technology Infrastructure Library

For the management of the exploitation of its services and Information and Communication Technology (ICT) an organization like the one in our case study can build on IT Service Management (ITSM). ITSM is the discipline that strives to better the alignment of IT efforts to business needs and to manage the efficient providing of IT services with guaranteed quality (Brenner, 2006). Its de facto standard methodology is the IT Infrastructure Library (ITIL) which has been published in the UK by the Central Computer and Telecommunications Agency (CCTA) (2000) since the late 1980's (Brenner, 2006) where it emerged when the public sector started privatizing the exploitation of ICT and the principal wanted to have a grip on the services provided by these privatized ICT departments. This called for the gaining of insight in the tasks to be dealt with by an ICT organization. Not only the description of tasks viewed apart is important, but also the relationship between various tasks and the course of the processes within the various tasks must be clear (Van Den Eede & Van de Walle, 2005). Implementation of ITIL must lead towards implementation of process management supplying services meeting a certain service level (Thiadens & Spanjersberg, 2000). ITIL can be best labeled a 'Best-Practices-Framework' (Sewera, 2005) and is at this point in time the only comprehensive, non-proprietary, publicly available guideline for IT Service Management (Potgieter, Lew, & Botha, 2005). Although ITIL covers a number of areas, its main focus is on Service Support and Service Delivery (Janssen, 2003). The process under study, incident management, comes under Service Support, together with four other processes, as depicted in Figure 3.1. Their further discussion remains outside the scope of this dissertation. For the purposes of our research, we can restrict ourselves to a discussion of the Incident Management Process.

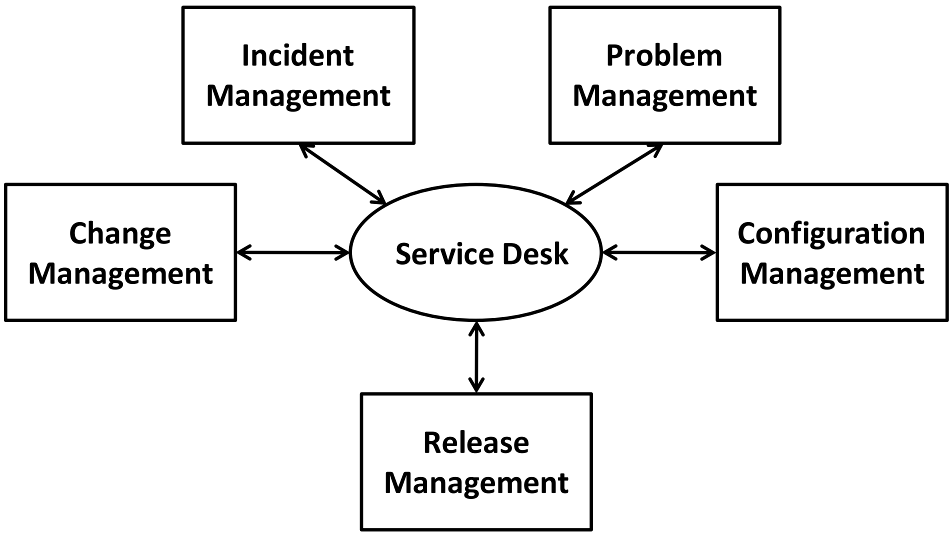

Figure 3.1 - ITIL Service Support Module (Adapted from van Bon, Kemmerling, Pondman, & van der Veen, 2004)

Incident management

Under ITIL, an incident is defined as a deviation from the (expected) standard operation of a system or a service that causes, or may cause an interruption to, or a reduction in, the quality of the service. It refers to "*any event which is not part of the standard operation of a service and which causes, or may cause, an interruption to, or a reduction in, the quality of that service*" (CCTA 2000, p.71). Example of incidents may be degradation in the quality of the service according to some measure of quality of service, the unavailability of a service, a hardware failure, or the detection of a virus. Users are the people who use the IT services in the business domain of the organization. The objective of Incident Management is to provide continuity by restoring the service in the quickest way possible by whatever means necessary (temporary fixes or workarounds) (Bartolini & Sallé, 2004). In this respect, Figure 3.2 illustrates the parameters that time to repair or downtime is composed of.

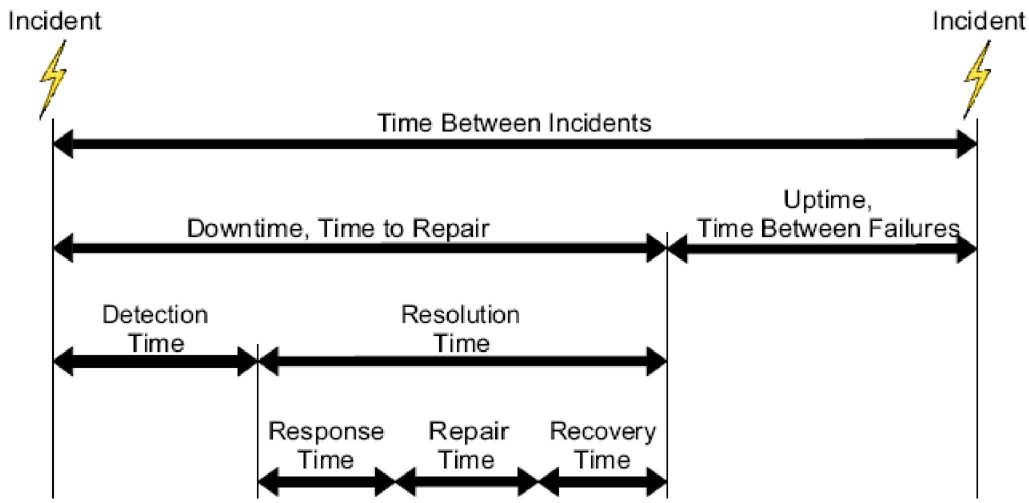

Figure 3.2 - Parameters influencing downtime (Brenner, 2006)

The detection time, i.e. the time until an incident is registered, can be shortened by technical measures like the use of monitoring tools (although in practice many incidents are still first reported by users to the service desk). The activities for the incident resolution however, mostly involve human intervention and their durations have a direct relation to typical Key Performance Indicators (KPIs) of Incident Management (response time, repair time) and Change Management (recovery time) (Brenner, 2006). Quintessential for a successful implementation of incident management is the presence of a Service Level Management ensuring continual identification, monitoring and reviewing of the optimally agreed levels of IT services as required by the business. Most targets set in a Service Level Agreement (SLA) are subject to direct financial penalties or indirect financial repercussions if not met. It is therefore critical for this management process to flag when service levels are projected to be violated in order for an IT organization to take proactive actions to address the issue (Bartolini & Sallé, 2004, p. 65). This means that tracking response, repair and recovery times is essential to achieving service level compliance. Incident priorities and escalation procedures are defined as part of the Service Level Management process and are key to ensure that the most important incident are addressed appropriately. (Bartolini & Sallé, 2004, p. 66). In the incident management process it is of fundamental importance to classify, prioritize and escalate incidents (Central Computer & Telecommunications Agency, 2000). Priority of an incident is usually calculated through evaluation of impact and urgency (Bartolini & Sallé, 2004, p. 66). For this purpose, the collection of sound statistical data from tracking Incident Management instances, is crucial (Brenner, 2006).

To understand the Incident Management process at the financial institution, we first discuss their organization of the Incident Management process, whereupon we explain how incidents are handled.

Organization of the incident management process

The financial institution has a special Service Management division that coordinates the ITIL processes throughout the organization. One of the Service Management division's staff members is the Incident Management process owner, in ITIL referred to as the Incident Manager (CCTA (Central Computer & Telecommunications Agency), 2000, p. 87). The Incident Manager is responsible for the efficiency and effectiveness of the Incident Management process. The Incident Manager monitors the Incident Management process, maintains the Incident Management information system, and makes recommendations for improvement. The financial institution uses a special IT Service Management application suite, Peregrine Systems' Service Center, which is designed to support ITIL's best practices.

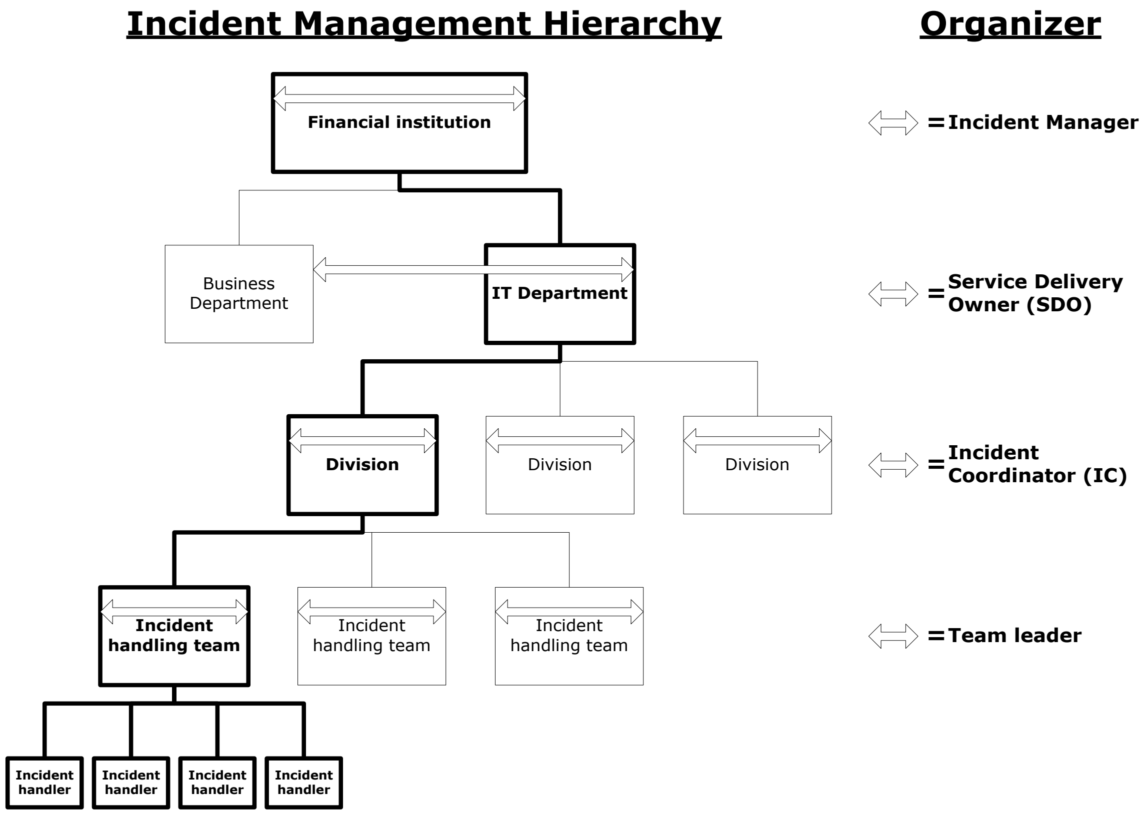

Figure 3.3 - Organization of the Incident Management process (Muhren, 2006)

ITIL's main tool to monitor a process is to set KPIs. KPIs are defined as "*clearly defined objectives with measurable targets to judge process reliability*" (CCTA (Central Computer & Telecommunications Agency), 2000, p. 88). Every month the Service Management division issues a report on the reliability of the various ITIL Service Support processes, making use of the prescribed KPIs.

The financial institution offers many services to their customers, for example asset management activities, financial transactions, and online Banking. To support all these services, many internal services have to be in place. The financial institution has split up all her activities into service domains, and each of the over 70 service domains maintains one internal or external service. Every service domain has a Service Delivery Owner (SDO) in place, which is responsible for supporting the service domain by the IT department. The SDO has a good overview of all activities within a service domain, from the IT department to the users in the business divisions, and is therefore an important contact person when incidents occur in a service domain. In literature on organization theory this role is known as 'boundary spanner' as it enables transgressing the departmental boundaries (Williams, 2002).

Each division of the IT department has its own Incident Coordinator (IC), who is responsible for the Incident Management activities within his division. The IC coordinates the Incident Management activities of the teams in his division and communicates directly with the SDO when a higher priority incident occurs. ICs provide the Incident Manager of recommendations for improvement of the Incident Management process. Within each incident handling team there is a team leader, who functions as the contact person for the team.

Incident management process

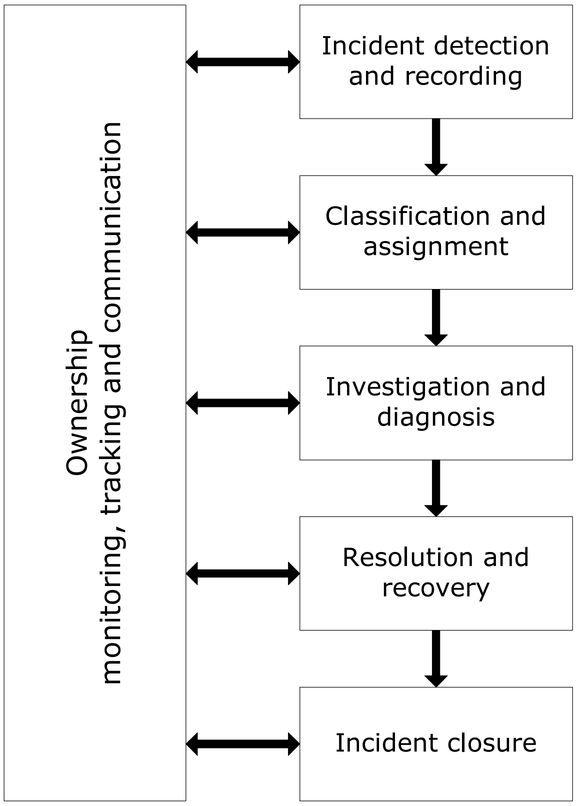

Figure 3.4 - The Incident life cycle (adapted from CCTA (Central Computer & Telecommunications Agency), 2000)

Now that we have seen how the Incident Management process is organized, we can continue with examining how incidents are actually handled at the financial institution. As the maturity of the Incident Management process of the financial institution is very high compared to ITIL's best practices and the same process at other companies, we discuss ITIL's Incident Management process according to the implementation at the financial institution where we have conducted the research. Figure 3.4 gives a brief overview of the different steps in the Incident life cycle. A more extensive process layout is provided in Table 3.1. The process flow diagram can be found in Figure 0.1, under Appendix K.

It is important to note that an incident is constantly monitored by the owner of an incident, who makes sure the agreed resolution time is not exceeded and who communicates the status of the incident to the user.

Phase	*Role*	*Proc*	*Step*	*Status*
Registration	REG	1	Register the incident	Open
	REG	2	Classify the incident and assign it to a team	Open
Check the assignment	SOLT	3	Check the assignment of the incident ***Inbox: Incidents assigned to my team(s), with status'open' and 'accepted'***	
	SOLT	4	If the incident is assigned to the right team and you cannot start immediately with solving the incident, accept the incident.	Accepted
	SOLT	5	If you can start immediately with solving the incident, assign it to a solver. (fill-in 'assigned to user')	Work in progress
Diagnosis & Solution	SOL	6	Analysis ***Inbox: Incidents assigned to me, with status 'Work in progress'***	
	SOL	7	Work out (a part of) the solution	
	SOL	9	Implement <u>**temporary solution**</u> (solution with aftercare)	Flag 'Temporarily bypassed'
	SOL	8	Implement <u>**permanent solution**</u>	Resolved
Verification & Closing	COO	10	Check the solution of the incident ***Inbox: Incidents registered by me, with status 'Resolved'***	
	COO	11	Close the incident	Closed
	COO	12	Reopen the incident	Open

REG = Registered by SOLT = Team Solver SOL = Solver COO = Coordinator

Table 3.1 - Description of the Incident Management process

Incident detection and recording

When a user encounters difficulties in continuing his work, he calls the Service Desk, the first-line support for incident handling in the organization. If the phone call is just a request for information, or the service desk employee can solve the difficulty immediately, it is registered in Peregrine as a 'call'. No further actions are required and the user can continue his/her work. If the difficulty cannot be solved immediately, the Service Desk registers it as an incident. An incident ticket is then created in Peregrine and all possible incident details are entered in the ticket. From this point onwards, the Service Desk is the owner of the incident and is responsible for the timely handling of the incident and the communication to the user. The user needs to be updated regularly on the status of the incident.

An incident can also be detected by operational personnel. Operational personnel could either be the cause of the incident, or they were just able to detect the incident in their day-to-day activities before any service disruption was noticed by a user. It is a common procedure for them to register the incident themselves in Peregrine. In this case, they are the owners of the incident and coordinate the incident until it is solved. In the remainder of the thesis, we focus on the normal procedure that the Service Desk coordinates incidents.

Classification and assignment

By asking targeted questions, the Call Desk can estimate the priority of the incident. The priority is set by determining the impact and urgency of the incident. The impact of the incident must be determined from the company's perspective and indicates the (potential) financial loss the incident can cause. There are four different degrees of impact (Table 3.2) and three different levels of urgency (Table 3.3) an incident can have.

Impact level	*Impact qualification*
1	Very many users are impacted (e.g. the entire head office)
2	Many users are impacted (e.g. a few branches or several divisions)
3	Few users are impacted (e.g. one branch or one division)
4	One user is impacted

Table 3.2 - Incident Impact Level (Bank)

Urgency level	*Level qualification*
1	Very urgent
2	Urgent
3	Not urgent

Table 3.3 - Incident Urgency Level (Bank)

The priority is set by adding the impact and urgency degree and decreasing it by one. So the highest possible priority is 1, the lowest is 6. The timeframe within which the incident must be solved is formulated in Service Level Agreements and can be found in Table 3.4.

		Impact			
		1	2	3	4
Urgency	1	2 hours **1**	2 hours **2**	4 working hours **3**	4 working hours **4**
	2	4 hours **2**	4 hours **3**	12 working hours **4**	12 working hours **5**
	3	10 days **3**	10 days **4**	10 days **5**	10 days **6**

Table 3.4 - SLA Time frames

It is possible that the Service Desk is able to handle the incident, but cannot do this immediately. The incident is then assigned to the Service Desk. In most cases the Service Desk does not know what is causing the incident or how to solve it, so they must make an appeal to people with more expertise: second-line support groups, having more specialist skills, time or other resources to solve incidents (CCTA (Central Computer & Telecommunications Agency), 2000, p. 74). Because the Service Desk inquired the user about the incident, they will have an idea on what could be causing the incident or at least in what area to start investigating it. In Peregrine, a list of teams appears that could be consulted for this kind of incident. The Service Desk assigns the perceived most suitable team to handle the incident.

People from the IT department are split up into teams that each has their own specialization. These are virtual teams, because they could comprise people who work in different divisions and/or at different locations. They all have access to Peregrine, and when an incident is assigned to a team, it appears in the mailbox of the specific team and each team member can assign the incident to himself or herself. The team member that assigns the incident to himself/herself is called the incident handler. When the incident appears is assigned to the wrong team, it is sent back to the sender.

Investigation and diagnosis

The incident handler will investigate the incident and try to find a solution or a workaround. It is possible that a solution can only be implemented after some time, e.g. at a new release. A workaround could be suggested that will help the user until the real solution is implemented. When a team member cannot identify the underlying cause of the incident and propose a solution or workaround to it, the incident can be further rerouted to a higher-line support team, even an external vendor, until a solution to the incident is found.

Resolution and recovery

The incident handler implements the solution or the workaround, takes all necessary recovery actions and updates the documentation of the incident in Peregrine by describing how he/she solved the incident.

Incident closure

The Service Desk contacts the user to make sure the proposed solution is satisfactory. If this is not the case, the incident is sent back to the incident handler. The Service Desk closes the incident when the user is satisfied with the proposed solution.

Security incident handling

Not all incidents are handled in this manner. Incidents that are a (potential) threat to the confidentiality or integrity of the information or even the organization, or incidents that have impact on the availability of the systems or networks and are suspected to be caused by criminal intent, are handled in a special process. This security incident handling process is not the scope of this thesis.

Incident briefing

Every morning the incidents with a priority code one or two that occurred the day before or still have an open status are discussed at a 'morning briefing'. Employees who solved the incident or know more about it, explain the cause of the incident and the (proposed) solution to a public comprising general managers, incident process coordinators, service delivery owners, and other IT staff that is involved in Incident Management or just is interested. A staff member of the Service Management division serves as the chair of the meeting. Half an hour before the briefing, potentially interested employees to attend the briefing can read a document on the intranet that describes the incidents that will be discussed. The briefing can be attended 'live' at the head office of the financial institution or at another office via videoconference.

2.2 NPP Case[42]

2.2.1 The company

The NPP under research is part of a European energy company which core businesses are (1) sales of electricity, natural gas and energy products and services; (2) electricity generation; (3) electricity and natural gas trading; and (4) management of electricity and natural gas networks, on behalf of distribution system operators. The company[43] employs over 15.000 staff and realizes a turnover of over 12 billion Euros. It operates seven nuclear reactors and has numerous thermal plants as well with which it generates over 130 000 Giga Watt Hour (GWh) electrical power[44]. According to recent national legislation, nuclear power should be phased out, starting in 2015, which puts a large amount of stress on the organization. Equally noteworthy is that large scale commercialization of power production in Europe has unleashed a series of mergers and acquisitions that probably will continue for a while stressing the volatility of the European energy market.

2.2.2 The Nuclear Power Plant

Reactors

The site houses four reactors, all of the Pressurized Water Reactor type. The two older reactors share various systems, among which a control room with separate consoles for each reactor, which makes them virtually unique. Their tight association accounts for the fact that these reactors are referred to within the plant as 'twin-reactors'. They have a generating power of about 400MW. The other two reactors are of a more modern breed and although identical, they are separate entities, both generating some 1000MW. The reactors themselves and closely connected machinery such as steam generators and tools for fuel manipulations are housed in circular containment buildings, as is usual for reactors of this type. The turbines and other machinery are housed in adjacent machine halls. The control rooms and offices of staff that are closely involved in operation of the installations are in buildings that are connected to the machine halls and reactor buildings. Separate buildings house administrative staff, workshops used by maintenance personnel, a restaurant and a wastewater facility. This facility deals with all the water that is used and discarded on the site, also by the actual nuclear installations, and it therefore fulfills an important function by taking care that no contamination leaks from the site into the environment. The two gigantic cooling towers and the eternal clouds of water vapor rising up from them can be seen from many miles. The site itself is dominated by a vast network of power lines crisscrossing the site and their continuous buzzing.

Maintenance regime

Both Maintenance & Repair work constitute a major part of the activity that takes place on the site of the power plant. Repair work is usually incidental of nature; whenever a defect is found, a notification is issued and the repair of the device is scheduled (a more detailed description of this process can be found below). Repairing defects is an activity that cannot be foreseen and planned a long time in advance in most cases. Maintenance work differs in that respect: maintenance work is planned for very long periods, some activities are dictated by (inter)national legislation or the plant's designer and are planned for five or ten years. The complexity of a nuclear power plant, the sheer numbers of machines and devices and the narrow tolerances some parts and devices must function within, lead to elaborate maintenance plans. Information technology forms a vital aid in managing these maintenance plans. Periodic maintenance is automatically planned and interdependencies between parts that play a role in the maintenance planning are automatically monitored.

In order to achieve an efficient maintenance regime that requires as little downtime of the reactors as possible, many maintenance activities are bundled per reactor and are executed within a time span of three to six weeks, during which the involved reactor is brought to a halt. These intensive maintenance periods are called 'revisions'. They are not only used for maintenance, they also offer the opportunity to install new or updated instruments in places that cannot be accessed when the reactor and connected machinery (such as steam generators and turbines) are operational. Every reactor is subjected to one revision each year, with one major revision every four years. During revisions, maintenance crews are active 24/7 on the site and a single shift for a team can last up to fourteen hours. Not surprisingly, revisions are experienced by the NPP personnel as very intensive and stressful periods offering little opportunity for rest or time to spend with families. This is compensated for during the periods between revisions, when employees can go on leave. A major reorganization in 2001 has had an important influence on the organizational 'tides' that are dictated by the revisions. Before the reorganization, each reactor had its own maintenance team. This implied that each maintenance team had one revision on hand each year. Currently, each maintenance team works on a limited set of components *all over the site*. This means that each maintenance team now faces four yearly revisions. This imposes a much larger amount of stress on the maintenance crew and makes it more difficult for workers to take up leave and follow job-related courses.

Organizational Structure

In this section, a general overview on the organizational structure of the power plant will be provided. Please note that this overview only concerns this particular plant; it does not reflect any part outside the plant itself. The overview in this chapter is predominantly assembled from information interviewees provided during the data collection stage of the research and observations made on-site by the researchers.

One of the goals of this reorganization was to make the plant operate more efficiently by increasing cost awareness on behalf of the plant's staff. One of the ways to make operational personnel more aware of the costs of their actions was the introduction of an internal customer-supplier model. This model dictates that whenever a task must be performed or a part must be ordered, a request should be sent by the asking team to the EMS division (Electro-Mechanical Services), who should in turn respond by sending an offer, which can then be accepted by the team that identified the need for the service or product. In order to make things run smoothly, a division was put in place that could aid in the negotiation process. Other changes in structure after the 2001 reorganization include the transition from entity-based teams to functionally oriented teams. Before the reorganization, each reactor and the water treatment facility had its cross-functional, own servicing team, consisting of specialists for every function that existed within the part of the plant the team was responsible for.

2.2.3 Maintenance & Repair Process

In this subsection, the Maintenance & Repair process, which is the actual focus of this research within the power plant, is described. It is important to note that Maintenance & Repair jobs run through the process in much the same way with only minor differences. The flow of a typical job (Figure 3.5) is followed from the point where it originates until the spot where the job enters the filing cabinets as a piece of documentation for further reference.

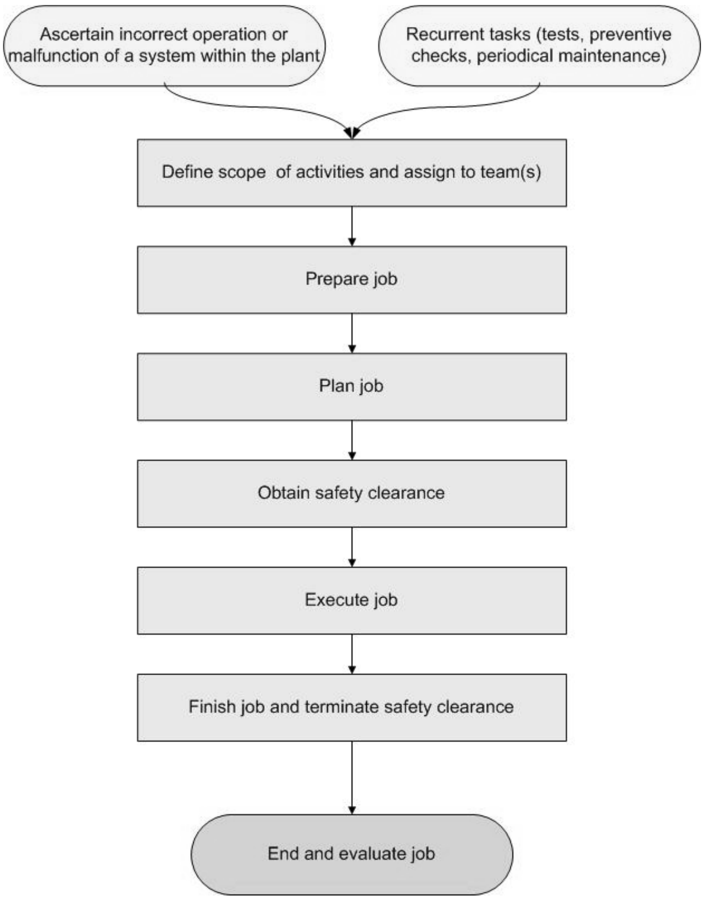

Figure 3.5 - Maintenance & Repair process (Vanhuysse, 2005)

For a comprehension of the Maintenance & Repair process, it is important to realize that there are three important types of administrative entities that play a role in the process: notifications, work orders and work clearance applications.

Notifications

Any employee that observes a malfunction can create a notification or deviance in the plant and it includes information like the description of the anomaly, a priority index estimated by the reporter of the problem and a required end date. The priority index is a number varying from 0 (zero) to 3, 0 indicating a severe problem that must be dealt with immediately and 3 indicating a problem that needs to be solved, but that does not necessarily needs to be dealt with in the short term. The ultimate execution date is an additional piece of information that provides insight into the relationship between the priority (which should be regarded as a measure of importance rather than actual priority) and the haste that is involved in the issue. For example, a notification can have a priority level of 1, which denotes a fairly urgent/important job, but an ultimate execution date that lies several months in the future. This means that the issue is very important indeed, but that there is no necessity to immediately take action. This might seem contradictory, but in practice it does not need to be, for instance if the notification involves an additional safety requirement that is imposed by law, but does not need to be implemented before a specified date. If a specific device is involved in the notification, the reporter of the notification is required to put a paper tag in place on the device to indicate that a malfunction or deviance has been noted and reported. In the remainder of this dissertation, for the purpose of our research, the terms 'notification' and 'incident' are use interchangeably.

To give an impression of the scale of operations: in 2004, more than 36,000 notifications were created.

Priority level	*Description*
0	Critical; must be dealt with on very short term
1	Crucial, but can be planned
2	Important
3	Required

Table 3.5 - Priority levels in the M&R process (NPP) (Vanhuysse, 2005)

Work orders

The second important entity is the work order. A work order contains a description of the activities that are part of the actual job. A work order can either be the result of a maintenance request (entered manually or automatically planned by the information system), a malfunction report (in this case, a notification precedes the work order), a modification request (a request for modifying the plant in some way) or it can be generated by a work preparator as part of a higher level job. During the work preparation phase (see section 'Work preparation'), the global information in the order is expanded and details are added that are necessary for the execution phase of the job. This information includes a short description of the work to be performed, a cost estimate and the device in the plant that is involved in the job. Workers must be able to present a printed version of the work order of the job they are currently working on (work permit). That way, they can prove that the job has been prepared properly and that the workers have been instructed on the particularities of the job. The total number of work orders created in 2004 gives an impression of the scope of the Maintenance & Repair process: in that year, more than 73,000 work orders were processed.

Work orders vs. notifications

The apparent discrepancy between the number of notification (36,000) and the number of work orders (73,000) requires some explanation. In fact, even though the numbers may seem contradictory, they indicate the nature of the relationship between both entities, which is essential to the understanding of the Maintenance & Repair process. As explained earlier, the start of most Maintenance & Repair tasks is the creation of a new notification. If deemed necessary, such a single notification is forwarded to a servicing team. The servicing team will then further investigate the scope of work that needs to be done and creates the required work orders to be executed by the team's workers. Additionally, a job may require auxiliary activities performed by other teams, such as decoupling a device and testing machinery after a repair job has been completed. A servicing team can create work orders and directly assign them to other teams without a notification preceding those work orders. In short, this means that a single notification can theoretically lead to any number of work orders, which accounts for the difference in the number of notification and the number of work orders.

Work clearance applications

The third entity that exists in the Maintenance & Repair process is the work clearance application. In Chapter 1, the concept of tight coupling was introduced. This tightness of coupling has a direct effect on Maintenance & Repair jobs that constitute a major portion of the work that takes place on the site. Along with the fact that building a nuclear power plant is an immensely cost-intensive endeavor, which implies that once the project is realized, the plant is expected to be operational most of the time[45], the interconnectedness of the plant's systems implies that most maintenance work will be performed on 'live' parts of the installation or systems that are directly connected to working parts of the plant. In order to ensure safe working conditions, the circuits and devices that are subject to maintenance or repair activities, must be shut down or de-coupled before actual work takes place. Therefore, EMS teams must file a request for consignation of the systems they are planning to work on (the so-called 'work clearance application') in order for Operations to decouple and inactivate these systems at the right time insofar as the operating and testing schedules as well as other ongoing work on the plant allow it. Consignation requests are involved in nearly every job in the plant and form an important part of the communications between Operations and EMS. The work clearance applications are created and processed in parallel to the creation and processing of the work orders they accompany. Once clearance is granted by Operations, a printed version of the work clearance application is used on the work floor as a permit to start work. Together with the work order itself that is provided by a work preparator from EMS, the printed work clearance application provided by Operations constitutes a worker's permission to perform a specific task.

Daily Committee Meeting (DCE)

The first step all corrective jobs in the plant go through is an evaluation of all new notifications. New notifications are assessed on a daily basis by a committee ('DCE'; Daily Committee meeting per Entity), including expert members from both Operations and EMS. Along with work in progress, these new notifications are reviewed one by one and decisions are made whether a notification requires action to be undertaken, the assigned priority is correct, what kind of work must actually been done, which servicing team(s) would be most suited to handle the job and whether the job requires any particular safety measures. For example, jobs that involve work on the reactor building penetrations (through which control lines, steam pipes and cables for measurement devices run) are always treated with special care as they can possibly cause disturbances in the containment of the reactor and therefore constitute a serious risk. Also, new notifications are related by the committee to work in progress and the operating and testing schedules of the plant to ensure that no conflicts will arise when a job is started. Therefore, the multi-disciplinary nature of the DCE committee, induced by the presence of expert members from different divisions, is vital.

Planning

After the scope of the work has been determined and any conflicts with other activities on the site are avoided or resolved, the notification is forwarded to the EMS team the job has been assigned to. The sub chief of this team collects the jobs forwarded to him and assigns them to his work preparators. These work preparators in turn communicate their job portfolios to the planners, along with a proposed execution date for each job. The planners create a planning, which incorporates all the jobs that are assigned to the teams, but at the same time takes into account the available work force and other activities at the site in order to avoid conflicts as well as to benefit from advantages that result from grouping specific orders. For example, two work orders on the same electromotor can be scheduled adjacently so that the motor need only be decommissioned once for both jobs to take place. It is essential that the planners are constantly communicating with both EMS and Operations to remain updated on the current Maintenance & Repair situation as well as the current operation and testing situation of the plant. One way to achieve that is through weekly recurring planning meetings that are attended by the work preparators and the planners. The planning scope for day-to-day work is three weeks. For revisions, specific schedules are created that span the entire period of the revision.

Work preparation

As soon as a job is assigned to a team, the preparation of the work can take place. Typical activities in the preparation stage include an on-site inspection of the problem of the device to be serviced, the ordering of replacement parts, finding any repair procedures that exist within the organization for this particular job or creating a new procedure if no existing method can be found, creating a risk analysis for the job, adding information to the work order and creating a work clearance application for each job. If a job involves activities that fall beyond the scope of the team the job is assigned to, the job preparator can issue additional notifications (sub-jobs) directly to teams that have the necessary competencies. The work preparators who are responsible for these tasks are mostly employees that started out at the plant as workers (welders, mechanics) and were promoted to work preparator level. Their work floor experience provides them the necessary insight to perform their job. Moreover, work floor employees from EMS teams indicated during the interviews conducted in this research that practical experience grants work preparators the credibility they sometimes need to convince the workers that the proposed working methods are the optimal compromise between efficiency and safety.

Job execution

As soon as a job is prepared and safety clearance is provided by Operations, a team of workers receives a printed work order and the job can be executed on the scheduled time. Activities that are regarded part of the job execution phase include the actual work itself, as well as safety measurements (performed by both Classical Safety and Radiation Protection officials), testing of the involved devices, followed by a canceling of the safety clearance and debriefing of the involved team(s). Of prime importance during work execution is the STAR principle, which stands for Stop Think Act Review. This principle is employed to make workers aware of their actions and to ensure that they go about their work in a conscious way. Forms are being used on which the workers are required to record, for example, that they are aware of the safety measures that apply to the job and that their job site is safe. As soon as a job has been completed, its status is set to 'WOCO' ('Work Order COmpleted') in the information system. Any tags that were put in place on devices when the notification was issued (in case of course a notification was involved) are being removed by the workers in order to make it clearly visible that the work has been completed.

Documentation

The final phase a job runs through is the documentation phase. Documentation of the work essentially takes place on two different levels: first, the team that has performed the work documents any particularities of the work in the central documentation of the plant and/or in the team's own documentation set. On an evaluation form, the team can indicate whether all post-maintenance/repair tests have been passed and also whether the procedures that have been used in the maintenance/repair activity should be revised. Routine jobs do not receive much attention from the teams that have executed them as a specialized documentation department ('Work Settlement') takes care of documenting every piece of information that is available after a job has been performed and there is no need for the servicing teams to spend time on this routine documentation work. The Work Settlement department receives all work orders that have been used by the workers to perform their activities and all information on these orders is entered into the plant's documentation. This way for example, information on spare parts used for repairs can be located by servicing teams in future occurrences of identical or similar jobs and historical data can be used to spot recurring problems and discover trends in defects. When a work order has passed through this final phase of its existence, it is marked 'teco' ('TEchnically COmpleted') and it is filed away for future reference.

3 Hermeneutics

3.1 The origins of hermeutics

Madison (1988) has proposed a list of criteria that act as methods for hermeneutic interpretation. The criteria included properties to be found in interpretations such as *coherence*, *comprehensiveness*, *penetration*, *thoroughness*, *appropriateness*, *contextuality*, *suggestiveness*, *agreement* and *potential*. They are explained in more detail in Table 3.6. It should ensure that the judgments or conclusions arrived at are not gratuitous or the result of subjective whim (Madison, 1988, p. 28). This is in line with a concern expressed by Walsham (1995) where he states that interpretive researchers should have a view of their own role in the complex process of "*accessing other people's interpretations, filtering them through their own conceptual* *apparatus, and feeding a version of events back to others*" (Walsham, 1995, p. 77). These principles challenge researchers to question their interpretation, especially given that the collection of data involves the researcher's own subjectivity (Butler, 1998, p. 292-293). These principles were employed throughout the interpretive process in both our case studies as an aid in arriving at a deeper interpretation of the phenomenon and is component parts. Together with a knowledge and familiarity with the hermeneutic circle of understanding as the core concept of hermeneutic thought and of the central role of the dialectic is vital for the hermeneutic researcher (Butler, 1998, p. 293).

Coherence	The interpretation must be coherent in itself; it must present a unified picture and not contradict itself. This holds true even if the work being interpreted has contradictions of its own. The 'interpretor' must make coherent sense of all the contradictions.
Comprehensive	This concerns the relation of the interpretation in itself to the work as a whole. In interpreting texts, one must take into account the author's thoughts as a whole and not ignore works, which bear on the issue.
Penetration	It should bring out a guiding or underlying intention in the text i.e. recognizing the author's attempts to resolve a central problematic.
Thoroughness	A good interpretation should attempt to deal with all the questions it poses to the interpreted texts.
Appropriate	Interpretations must be ones that the text itself raises and not an occasion for dealing with one's questions.
Contextuality	The author's work must be seen in its historical and cultural context.
Suggestiveness	A good understanding will be fertile in that it will raise questions that stimulate further research and questions.
Agreement	The interpretation must agree with what the author actually says. This is in contrast to reductive hermeneutics characteristic of Marxism or Freudlanism.
Potential	The interpretation is capable of being extended and continues to unfold harmoniously.

Table 3.6 - Methodological principles for the interpretive process (Madison, 1988;Uysal, 2009, p. 7)

In the positivist view on science, experience is thought to be the only source of meaning and the only source of knowledge. This is known as the Verification Principle: only assertions that are in principle verifiable by observation or experience can convey factual information (Gregor, 2006). The purpose is to explain (*Das Erklären*) the complex world. Generally speaking Organization Science research can be classified as positivist if there is evidence of formal propositions, quantifiable measures of variables, hypothesis testing, and the drawing of inferences about a phenomenon from a representative sample to a stated population (Orlikowski & Baroudi, 1991) (Klein & Myers, 1999, p. 69). The interpretive tradition on the other hand, steers researchers towards a different outlook, where the primary goal is not to develop theory that is testable in a narrow sense (although its validity or credibility may still be assessed), but in understanding (*Das Verstehen*) the complex world. "*[…] interpretive researchers insist that any observable organizational patterns are constantly changing because, as Parmenides observed, 'you cannot swim in the same river twice'*" *lnterpretivists argue that organizations are not static and that the* *relationships between people, organizations, and technology are not fixed but constantly changing. Therefore, interpretive research seeks to understand a moving target. In so far as each instance is treated as a unique historical occurrence, interpretive research is idiographic*" (Klein & Myers, 1999, p. 73).

Several interpretative approaches are possible, of which phenomenological hermeneutics is one (Butler, 1998, p. 285). It is elaborated on under the next section. Hermeneutics is defined as the theory or philosophy of the interpretation of meaning (Butler, 1998, p. 286). Several types of hermeneutic research approaches exist (For an overview, see: Butler, 1998, p. 286) but we adhere to the pragmatic-constructivist approach where interpretation involves entering into the interpretative norms of a community and where meaning operates and is to be found within the historical contexts of the interpreter and interpreted. This approach is based on Martin Heidegger and has amongst its proponents Hans Georg Gadamer and Ludwig Wittgenstein. We take a Gadamerian approach to our research, since it is characterized, not by a pure attempt to apply any pre-existing theory to the domain in question, but rather by the attempt to think from within that domain, and in a way that is attentive to it. In that sense, application of theory 'is neither a subsequent nor merely an occasional part of the phenomenon of understanding, but co-determines it as a whole from the beginning' (Malpas, 2009, citing Gadamer in: Truth and Method, 1989, p. 324) Theory and application do not occur in separation from one another, but are part of a single hermeneutical practice (Gadamer, Weinsheimer, & Marshall, 2004).

3.2 Hermeneutic circle

Perhaps the most fundamental tenet of hermeneutics is that understanding has a circular structure. Understanding works in broadening concentric circles, hence Heidegger's labeling it the hermeneutic 'circle of understanding' or in short hermeneutic circle. The unity of understood meaning expands in concentric circles, for instance from A through E, like in Figure 3.6. Important in this respect is that in understanding phenomena one remains permanently determined by the anticipatory movement of 'for-understanding' (i.e. pre-understanding' or prejudice) (Butler, 1998, p. 291). *The interpretation of a phenomenon (the hermeneutic whole) begins by the examination of its component phenomena (the parts). However, understanding the component phenomena can only begin when their relationships to the whole have been determined – the determination of these contextual relationships is itself guided by an expectation of meaning arising from the preceding context (e.g. derived from one's tradition-influenced prejudice). Through a dialectic process he will identify its parts. Operating from a holistic perspective and relationship to the whole consolidated into an emergent understanding of the phenomenon. In cycling through the circle of understanding, each part will be consolidated, and in so doing different perspectives will emerge – the horizons of interpreter and phenomenon will gradually fuse. This cycling through the 'circle of understanding' continues until the 'breakdown' has been repaired and the phenomenon achieves the status of a 'ready-to-hand' (i.e. understood, obvious).* (Butler, 1998, p. 291). Thus, as Gadamer (1988, p. 68) points out: "*The movement of understanding always runs from the whole to part and back to the whole. The task is to expand in concentric circles the unity of the understood meaning. Harmonizing all the particulars with the whole is at each stage the criterion of correct understanding. Its absence is failure to understand*" (Butler, 1998, p. 291).

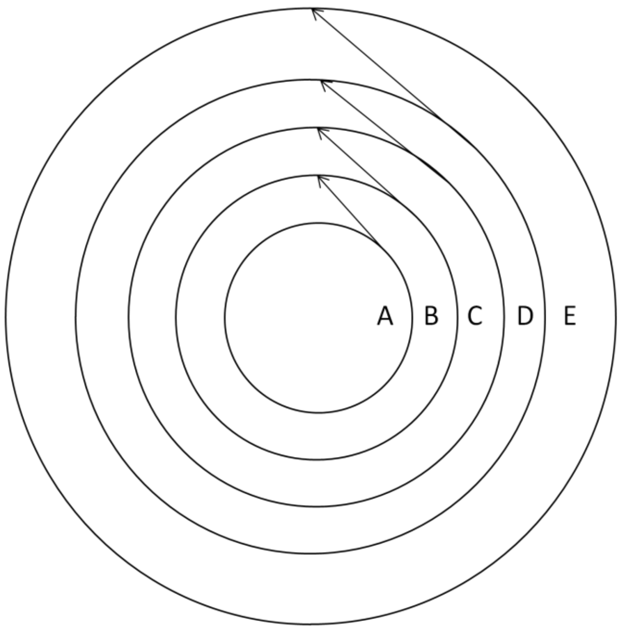

Figure 3.6 - Hermeneutic Circle (Butler, 1998)

The hermeneutic circle runs from understanding to explanation and back again. The understanding of a social phenomenon can only be reached by a dialectic process of narrowing the scope of generic concepts concerning it, and identifying the 'whole' the 'hierarchy of topics, or primary and subordinate topics', or primary and subordinate topics that constitute it – that is, its constituent parts (Butler, 1998, p. 291).

The hermeneutic circle constitutes a paradoxical concept. Whilst analyzing an object (e.g. a text, an interview transcription, a cognitive map), we 'break it down' into its component parts (words, paragraphs, constructs, nodes and so on). However, these parts only make sense in terms of the whole object. There is an endless dialectic, according to Heidegger, in terms of how we read, between reductionism (breaking the object down) and holism (reading it as a whole) (Wallace, Ross, & Davies, 2003, p. 590). This introduces a paradox: we can never understand an object without breaking it down, and yet we must look at it as a whole before we understand the individual parts. For Heidegger, this is a 'chicken or egg' situation: either step logically presupposes the other. Interpretative analysis is therefore a paradoxical action. In order to escape this paradox, we must make a 'leap' of subjective (non-rational) intuition 'into' the object. However, the correlate of this is that once the analyst is 'inside' the circle, understanding can proceed via a dialectical process and, therefore, progress. The object is broken down and then built up again: and each time this is done its 'meaning' becomes clearer (Wallace et al., 2003, p. 590).

Usually the primary investigator is both the inquirer into the phenomenon of interest and the analyst of the information about it. Thus, when interviews are used as the mode of inquiry, the analyst already has a sense of the text given by a respondent even before it is transcribed. Moreover, the act of transcribing deepens understanding so that, irrespective of whether or not the text as a whole is read and reread prior to the analysis of its particulars, the analyst has a sense of the meaning of the text as a whole. Thus, the hermeneutic circle is entered. In other words, the understanding of the whole of the text influences the understanding of a part of it, and the understanding of each part in turn influences the understanding of the whole. This circling of part to whole and back again results in progressive understanding that, in principle, is non-ending, although, hopefully, it reaches a kind of stability (Rennie, 2000, p. 484).

3.3 Relevance of hermeneutics for our research

In our research, we make the step to verification by taking the positivist strand of quantitative analysis of hypotheses. Our research methodology is one that tries to reconcile conventional theory-based design and hermeneutics. The essence of this approach is to view data not through the filter of an isolated theoretical abstraction nor as an unbounded collection of idiosyncratically interpreted, specific instances, but to recognize and analyze the multiple, simultaneous theories embodied by the data (Carroll & Kellogg, 1989, p. 13).

The most fundamental principle of hermeneutics is that of the hermeneutic circle (Klein & Myers, 1999, p. 71). It is a notion that implies that one can come to understand a complex whole from preconceptions about the meanings of its parts and their interrelationships. This is what our research aims at. The hermeneutic circle helps in figuring out contradictions between theory and data. Moreover, since our thesis is about paradox, there are plenty of contradictions that do not necessarily mean that the underpinning theory is wrong or that the research is wrongly designed leading to faulty data. Data-Theory is dealt with at the level of the part, whereas a theoretical conceptualization independent from data could lead us to understand why data does fit theory after all. In other words, what we suggest here is triangulation. Not only a triangulation of data, not only a triangulation of theory, but also a triangulation on the level of the research perspective, meaning an alternation of induction and deduction, of interpretative approaches and positivism. This calls for high-level conceptualization and very down to earth research. This starting point explains the eclectic research mix we applied in this thesis. In this subsection we point out why we attach great importance to hermeneutics through a triangulation approach of our research by taking a (1) conceptual, (2) methodical and (3) construct/theory perspective.

3.4 Triangulation

The research paradigm of triangulation requires that qualitative methods be combined with quantitative methods to allow for assessment of the general validity of research findings (Koch, 1993, p. 76). In addition, theory building was enhanced by insights gained from published research in related areas so that a triangulation of data and theory could be accomplished. Obviously, method, data collection, analysis, and theory stand in close relationship to one another.

We propose here a combination of methods that will approach the data from multiple perspectives, each designed to provide a specific insight into the topic, a triangulation of qualitative and quantitative methods. Sullivan and Beach (2002, p. 1424) define triangulation of data as the "*use of more than one form of data collection to test the same hypothesis within a unified research plan […] To minimize the degree of specificity of certain methods to particular bodies of knowledge, a researcher can use two or more methods of data collection to test hypotheses and measure variables; this is the essence of triangulation*". In our research design, this means that interviews will be supplemented by other forms of field data – in casu meeting attendances, the study of internal documents, direct observation or participant observation of action, and surveys (Walsham, 2006, p. 323).

The theories/set of constructs is another component of the instrument. Even though a researcher does not begin a project with a fully preconceived and uncompromising theory in mind, we are convinced that taking a promising theoretical lens as a starting point for research is indispensable. Contrary to what is suggested by Grounded Theory (Strauss & Corbin, 1998, p. 12), we do not believe that research begins just with an area of study and without a theory, allowing the theory to emerge solely from the data. Making the right choice regarding theory therefore here is quintessential in order to reach valuable research outcomes. The theoretical constructs we rely on have been described in detail in Chapters 2 and 3, but in the following section, we point-out their methodological appropriateness.

4 HRO Research Taxonomies

After the science-philosophical background of hermeneutic research described above, we now take the discussion to the level of what it all means for research in the field of HROs and make a plea for taking a holistic, integrative and comprehensive approach to research on HRT and SeMa. The field of reliability studies could benefit from adding other taxonomies to gain additional insight into the merits of the theories involved. For this reason, we have chosen taxonomies that help in juxtaposing our two main theories but not without stressing the necessary nuance and dynamics between them. We subsequently use the Positivist vs. Interpretive (4.1), the Normative vs. Descriptive (4.2), the Quantitative vs. Qualitative (4.3) and the Inductive vs. Deductive (4.3) taxonomy. The presence of 'versus' in these descriptions generally implies that the researcher must choose between one or the other. However, typical of hermeneutics is that a middle way does exist.

4.1 Positivist vs. interpretive

Orlikowski and Baroudi (1991, p. 5) posit that positivist studies are premised on the existence of a priori fixed relationships within phenomena and that they serve primarily to test theory, in an attempt to increase predictive understanding of phenomena. This would not serve us well because a pure positivist research tends to ignore that people shape their context. Thus, in this research we take a positivist position but one that has an interpretive aspect as well because of the instrument (i.e. HRT and SeMa) it uses[46]. This is in line with our theorizing on reliability from a systems thinking perspective, and more particularly from the perspective of dynamics and emergence (See: Swiss Cheese Model). This choice has three consequences for the nature of the conclusions that can be drawn upon the validation of the hypotheses put to the test. A first consequence applies to those hypotheses that are validated or falsified. A caveat is in place for their broader applicability than the cases. Because of the nature of the instrument, it cannot be guaranteed that the observations can be explained by the constructs we have relied on. In our survey of literature, we have found no evidence that constructs figuring under the HRT and SenseMaking label are exhaustive or limitative. A second consequence applies to those hypotheses that could not be validated or falsified. Our assertion is that the data underlying these non-validated hypotheses can contribute to a better understanding (*das Verstehen*) of organizational reliability, despite their inappropriateness for explaining (*das Erklären*). As a third consequence should be mentioned that whereas positivist research repulses bias, interpretative science (hermeneutics) acknowledges prejudice as an initial lens, as the necessary starting point of our understanding (Klein & Myers, 1999, p. 76). During the research however, this lens has to be adjusted to be in line with the research findings. However, it is important for the author to make this bias explicit because it helps in understanding the design.

4.2 Normative vs. descriptive

Traditionally organization theory distinguishes between normative (i.e. for making prescriptions) and descriptive (i.e. purely explanatory) approaches to organizations (Fucks, 2004;Donaldson, 1990, p. 373). This especially with respect to organizational culture, but – to a lesser extent – also to an organization's structure and coordination mechanisms. The normative approach is being identified with an Anglo-Saxon vision on organizing whereas the descriptive approach represents the continental European school of thought. We can use this opposing approach to learn about NAT and HRT. Both NAT and HRT can be considered normative theories. NAT, on the one hand, strongly recommends avoiding circumstances in which organizations/systems simultaneously tightly coupled and interactively complex. Therefore, Normal Accidents theorists (e.g. Perrow and Sagan) strongly recommend excluding nuclear energy production and nuclear warfare technology. High Reliability theorists on the other hand, clearly put forward solutions to solve the coupling/complexity dilemma. Although they stress there is no such thing as a unique recipe for reliability (de Bruijne, 2006, p. 63). This can clearly be seen in the formulation of their advices where they (e.g. Weick & Sutcliffe, 2001) use substantives that have the *look-and-feel* of imperatives (cf. Commitment to Resilience, Reluctance to Simplify, Sensitivity to Operations, Deference to Expertise and Preoccupation with Failure).

It is necessary to solve the normative-descriptive dichotomy before continuing our research. In fact, we believe it is not a dichotomy. The distinction between normative and descriptive is a theoretical one. Describing the situation as it is (descriptive) is a necessary condition for changing the organization (normative). Our research ambition is to be descriptive. More and broader research is needed for it to have the ambition to be normative. For instance, more research is needed on the set of constructs itself in order to make them more holistic. In addition, a larger set of case studies and/or a larger set of research units within the cases are needed as to reach conclusions that are more generalizable.

4.3 Quantitative vs. qualitative

Among the criticisms often leveled against recent research in HROs has been its heavy reliance on qualitative observation, the relative absence of testable hypotheses, the apparent lack of generalization to other kinds of organizations, and perhaps most seriously, the absence of an explicit theoretical foundation for this stream of inquiry (Creed et al., 1993, p. 56). Research on high reliability has been mainly qualitative, as well by NAT students (e.g. Sagan, 1993) as by their HRT counterparts (e.g. Rochlin et al., 1987). Whenever quantitative research methods are applied it is in the field of validating HRO in the field of safety, not reliability (Gary, 2003;Fratus, 2008). The same applies a fortiori to the study of NAT with only Wolf and Berniker addressing the issue quantitatively (Wolf, 2001). In their application of HRT in the field of reliability that goes beyond safety, Vogus and Welbourne (2003a) provided a notable exception. This limited application of quantitative methods should not come as a surprise since the general belief is that this research type is not suited to gain a thorough understanding of what constitutes (un)reliability (Weick, 1995).This is remarkable, because quantitative research can contribute to a better understanding of High Reliability.

Also on SenseMaking, the same critique of absence of quantitative research could be uttered. To the best of our knowledge we do not know of any published research that not only formulates hypotheses but that in addition puts them to the test. This observation is quite remarkable since SenseMaking lends itself perfectly for quantitative analysis as well: "*In the argument between qualitative and quantitative approaches to research, sense-making likewise refuses to choose a side. It is explicitly both qualitative and quantitative. […] Sense-making, […] assumes there is something systematic about individual behavior to be found by pursuing process orientations. In this way, then, sense-making casts itself as systematic qualitative research -- an approach with qualitative sensitivity which is amenable to the systematic power of quantitative analysis*" (Dervin, 1992, p. 81).

Our approach tries to remediate this shortcoming in the field of HRO and SenseMaking research. We strongly believe that in essence there is a false dichotomy between quantitative and qualitative research methodologies. Instead of being dichotomous, quantitative and qualitative research strategies are lying on an interactive continuum, with theory as the driving force (Basch & Gold, 1986). That way, our research has the potential of '*Erklären*' whereas in its quantitative aspects it has the potential of '*Verstehen*'.

4.4 Induction vs. deduction

HRT scholars from the first hour (notably La Porte, Rochlin and Roberts) have started their school of thought by observing high velocity organizations and systems (nuclear submarines and aircraft carriers). They collected individual ideas about what constituted reliability under tiring circumstances and derived from this a framework that could provide a coherent approach to safety and reliability (induction). Perrow on the other hand took a theoretical approach when he focused on the explanation of (near-) disasters (deduction) (de Bruijne, 2006, p. 62). Our approach is to combine both: we have started from observations by means of a risk analysis (induction) and went to HRT and SeMa constructs (deduction), which we have used for the construction of our survey (positivist), but have noticed that they were unable of explaining the data (deduction) so that we had to rely again on observations by means of an exploratory factor analysis (induction). The constructs derived thereof served for a positivist testing of hypotheses; the discussion of their analysis in its turn drew on theory. This is in line with Roberts and Creed (1993, p. 255) who state that "*[…] HRO research is moving apace from its earliest stages of primarily inductive and descriptive work to hypothico-deductive and prescriptive work*".

5 Research Approach

5.1 HRO Research guidelines

For our research on high reliability in high-velocity organizations, we have taken the guidelines by Roberts and Rousseau (Table 3.7) at heart.

Spend time in the system and engage in active discussions with members at all levels.
Build bridges and networks among research team and system members.
Consider the attributes researchers bring to the organization that may influence the research enterprise (for example, maturity, and gender).
Be concerned with messages conveyed nonverbally, as in dress and personal style, as well as those conveyed verbally.
Summarize information to protect anonymity before conveying it onward.
Learn and use organizational lingo.
Carefully avoid going native (for example, by rotating team members)
Use data from multiple sources and methods.
Employ comparison units within the organization (such as operational and support units) to identify distinctive characteristics of extremely complex organizations.
Maintain an organizational view by continually asking how a particular piece fits into the whole.
Preserve impartiality. Do not become the organization's advocate, nor its attacker.

Table 3.7 - Prescriptions for the Research Team (Roberts & Rousseau, 1989)

Not only the mind-set of the HRO researcher is of importance, also the attitude of the HRO manager, who acts as his sparring partner. For their part, managers of HROs ought to (Roberts & Rousseau, 1989) to co-operate as listed in Table 3.8.

1.	Develop a questioning stance vis-à-vis researchers to clarify the focus and scope of the research.
2.	Be ready to discuss and tackle problems important to the research.
3.	Engage in activities that use researcher skills in ways beneficial to the organization or its constituencies (e.g. identification of trouble spots).
4.	Listen and react to research results and feedback; check out and reality test conclusions.

Table 3.8 - Prescription for HRO Managers (Roberts & Rousseau, 1989)

While these recommendations may be good ones to make for any organizational research (Roberts & Rousseau, 1989), they are deemed essential in HRO research. Our research has taken into account all of them and this section describes the research mélange we have used to answer our research questions. In line with Moray (2000, p. 861) we posit that if one reflects on the findings of the HRT Founding Fathers, one can see not just that ethnographic and sociological methods must be added to the armamentarium of ergonomics research, but that an even wider approach is needed. For this reason, we collected data through a broad spectrum of techniques. First we explain how the case studies were prepared for (5.2). Next, we describe the different techniques used throughout the research (5.3 to 6) and finally we point out how this build-up fits the hermeneutic circle of understanding (7).

5.2 Case study preparation

5.2.1 Case study preparation

In a first phase, several meetings were scheduled to fully prepare for the research project. These included meetings with General Management and Operational Management. During these sessions the scope, interdependences, timing, budget and approach were fine-tuned between the two case organizations and its academic partners. Coordinating meetings were organized during which all participants were informed on the project and given the possibility to ask questions or provide feedback and additional remarks. These initial meetings formed the basis of further coordination of the research. Besides, we were granted full access to both the organization's company intranet so that we could consult all incident management related documents, including tutorials, process descriptions, legacy data etc. Besides, we had at our disposal all necessary resources (desk, PC, internet connection, print and Xerox facilities, access badge etc).

5.2.2 Researcher – subject interaction

Action research

If we want to do as we preach, our research had to reflect the characteristics of dynamics and emergence. At the same time, it had to be conducted in narrow collaboration with the organizations in which and for which it had been done. As we have argued above, this did not call for a mere quantitative or empiricist approach, but for a qualitative, ethnographic one (Woodward, 2001, p. 294). Therefore, asking people in a straightforward manner how they see things is not the right approach. Building an understanding of how they see things – in concert with them – is. This approach is generally described as action research, a technique involving researchers and practitioners in iterations of problem diagnosis, action intervention, and reflective learning. Action research combines theory and practice, researchers and practitioners (Avison, Lau, Myers, & Nielsen, 1999, p. 94). The particular approach we have taken in our study is a derivative form of this general action research tradition, with an emphasis on the fact that the researcher interacts with the research participants. We are convinced that "*data are not just sitting there waiting to be gathered, like rocks on the seashore*" (Klein & Myers, 1999, p. 74). Instead, data are produced in a social interaction (Klein et al., 1999, p. 74) (Klein et al., 1999, p. 74)of the researchers with the participants. Since action research is "*continuously refining methods, data, and interpretation in subsequent cycles, in the light of the understanding developed in the earlier cycles*" (Kasunic, 2005, p. 112), this approach suits the hermeneutic research style well. Worth mentioning is that on many occasions, two researchers collaborated on these cases. This constellation of working as a team offered broader opportunity to capture greater richness of data and to rely more confidently its accuracy (Benbasat, Goldstein, & Mead, 1987).

Ethnographic field study

No research remains free from simplification because researchers tend to bring in line their findings with their theory. It could be assumed (hopefully) that this is mainly due to the need to fit the research data in the research framework. This simplification is normal since in many cases research-opportunity does not offer the possibility to spend a lot of time in the 'bowel' of the organization. Some of the reasons for this are listed below:

- The time window often might be too small to get the occasion to spend a lot of time at the place the research is about. This especially is the case when investigating several organizations at the same time.

- The level of confidence to do research is sufficient to get full co-operation, but most organizations probably will feel they can do without someone looking over their shoulder, certainly, when this occurs at unexpected moments.

Unfortunately, it is only by talking to organization members about how things really are, what gives sense to what people do, by asking questions and dialoguing with others, that the 'as-is' (IST) can be distinguished from the 'to-be' (SOLL). The only way of getting to know whether there is a deviation between the way procedures are used (IST) and how they are supposed to be used (SOLL) is by 'sacrificing' valuable research time in order to gain enough confidence and finding the right tone of speech. It is only when researchers are at the same wavelength – of course still keeping the necessary independence – with the object of their study that the danger of simplification can be limited. "*Learning to feel the organization's pulse comes only through close attention, listening, experience and reflection. Trial-and-error and living with the organization over time can develop a deep knowledge and understanding of how the organization functions and what it takes to correct problems*" (Bennet & Bennet, 2004, p. 299) (Geyer & van der Zouwen, 2001, p. 299).

Therefore, based upon the purpose of understanding the incident management process in the context of the organization in which it is embedded, part of the data collection was conducted along the principles of an ethnographic field study. To this end field observations were done in the two organizations over a two year period (each), overlapping one year, so a period of in total three years. They were gathered on the perspectives of several organizational levels, going from senior management to people on the floor. In addition, this study includes both real-time observations and retrospective data (Brown & Eisenhardt, 1997, p. 3). For this observation, we got help from a team of master students[47]. At the Bank, these ethnographic field study activities included amongst others our presence at meetings, incident briefings and debriefings and project discussions of progress, but also – and at least as important – informal observations made and impressions gathered during lunches and coffee breaks. The same kinds of activities were conducted at the NPP. In addition, however, two idiosyncratic activities are worth mentioning and have resulted from the mutual trust between our research team and the NPPs senior management and staff. A first activity in that respect is that we were an observer at a training session at the plant's simulator training center. Second, a particular mention is our experience as an in person and in real-time witness of a severe incident at the plant's premises. This included our observation from the incident command procedure rollout, the decision making process and the incident debriefing. At all times, we kept daily records of these activities, providing real-time data (Brown & Eisenhardt, 1997, p. 5).

Previous research in HRO settings builds on ethnography as well. Gauthereau & Hollnagel (2005) for instance, in their effort of trying to understand a series of NPP incidents related to operational readiness verification, felt a clear need to understand work practice in its natural setting, i.e. the plant and thus the need for observations to be one of the sources of empirical materials (Gauthereau & Hollnagel, 2005, p. 121). Roberts and Rousseau (1989) called the need not only to focus on the activity of interest, but on the broader context "*to have the bubble*". Like Gauthereau & Hollnagel (2005, p. 121) we experienced nonetheless that it was not possible to separate the specificity of the process under research from its specific environment. Therefore, we had to combine direct, reactive and non-obtrusive observations of selected staff with in-depth interviews.

5.3 Interviews

5.3.1 Objective

In a next phase, a substantial part of the research data was collected using semi-structured interviews with individual organization members as primary evidence generation mechanism (Palvia et al., 2003). The purpose of these time-consuming interviews was to gain a deeper insight into the potential risks and to avoid Groupthink. Janis (1982b) originally defined Groupthink as "*a mode of thinking that people engage in when they are deeply involved in a cohesive in-group, when the members' strivings for unanimity override their motivation to realistically appraise alternative courses of action*". According to this definition, Groupthink occurs only when cohesiveness is high. It requires that members share a strong 'we-feeling' of solidarity and desire to maintain relationships within the team at all costs. When colleagues operate in a Groupthink mode, they automatically apply the 'preserve group harmony' test to every decision they face (Janis, 1982b;1989). Findings by Eisenhardt and coworkers (Pelled, Eisenhardt, & Xin, 1999) show that this is counterproductive because constructive criticism can facilitate vigilant problem solving. On the other hand, it needs mentioning that when individual values are shared within a group, there are implications for commonality in values that a group or organization might share. Together with Dhillon and Torkzadeh (2006) and following Weick (1995) we believe that by assessing individual constructs it is possible to understand group and organizational value systems (Dhillon & Torkzadeh, 2006, p. 296). We argue that this is a fortiori so when combined with aggregation techniques on the level of interview analysis like cognitive mapping (5.4.1) or with data gathering tools like GSS (5.5).

5.3.2 Interview organization

We conducted interviews during several-day site visits (Table 3.9). The 51 interviews we conducted were taped and processed via cognitive mapping (42) or transcribed (9). Interviews typically lasted 90 minutes, although a few ran as long as 120 minutes.

Case	*Total number of interviews*
Bank	22 (19+3[48])
NPP	29 (23+6[49])

Table 3.9 - Number of interviews conducted in both case studies

We used an interview guide to conduct the semi-structured interviews (Appendix A and Appendix B). In both cases, we asked respondents open-ended questions that let them relate their stories of how the incident management process (in particular and in general) had evolved. We asked probing questions to establish details e.g., when a particular incident occurred (Brown & Eisenhardt, 1997, p. 5). Both our interview guides had five sections, addressing the contextual and structural factors (Pugh et al., 1968) we presupposed to be of relevance when explaining the reliability of the incident management. It began with the background of the respondent and the domain he/she worked in. The second part of the interview focused on HR related issues (HR, Knowledge Management, Training, and Culture), the third part concentrated on the incident management process (Incident, Procedure, and Meta), the fourth part on the role of technology and a final section addressed the influence of other contextual and structural factors. The order in which these categories were addressed during an interview was not necessarily the order presented here. Quite on the contrary even, since the interviewer followed the pace and story lines of his/her interviewee in order to obtain the most genuine data possible. The approach taken in these interviews was one of risk identification (layer 1), but the deeper layer was a search for high reliability through the application of HRO and SeMa constructs. The outcome of this analysis constituted the basis for the development of the questionnaire developed in a later phase of the research.

5.3.3 Protocol development

It is not the answer, it is the question that matters. Questions therefore should be nuanced enough to allow for a nuanced answer. Straightforward questions like the ones we have asked in form of our research question are good as a start, but it is highly doubtful whether they are capable of delivering the desired results. If we ask shortsighted questions it should not come as a surprise that also the answer is shortsighted (Bellinger, 2008a), not useful otherwise than ad-hoc, on a wider scale or under different circumstances. Wisdom is the result of an integration/connection of problems. This can only be accomplished when the questions are asked that reflect this connectedness, which calls for a thorough preparation.
For this purpose – and starting from an interview protocol used in a similar research setting (Rutkowski, Van de Walle, Van Groenendaal, & PoL, 2005) – a generic questionnaire was developed that could be adapted to the specificity of the context of a Bank (Appendix A) and a NPP (Appendix B). The Bank Interview guide was tested by means of a pilot interview with the process owner and slightly adjusted as a result thereof.

After a short introduction on the subject and methodology of the research, as much autonomy as possible was granted to the interviewees to define the direction the conversation followed, thereby allowing them to put emphasis on subjects that seemed of importance to them within this context. On moments where the interview strayed too far away from the subject or whenever a theme appeared to be exhausted, the interviewers would redirect the conversation using a new question chosen from the previously prepared interview protocol. The questions were divided into a few categories that proved useful in earlier research, allowing the researchers to provide a little structure to the conversations (Smals, 2006, p. 50).

5.3.4 Interview organization and selection of interviewees

Interviews were scheduled with various participants/stakeholders of the Incident Management process and the Maintenance & Repair process of the Bank and the NPP respectively. The purpose of these interviews was to gather a broad view on possible risks concerning the processes under study. For this purpose at the Bank, two business domains have been selected that together provide a rich and varied context, leading to nineteen interviews in total (n=19). The participants in these interviews are staff from both business domains, ICT domains, ICT audit, Operational Risk department, management and the ICT security department. At the NPP, staff from all of the Plant's departments: Operations (3), Maintenance (13), Assets (4) and Care (2). Additionally, one contractor was interviewed as well (1), bringing the total number of interviews to twenty-three (n=23). Interviewees were selected based on their involvement in the Maintenance & Repair process. In selecting the interviewees, the organizations have been very helpful by proposing employees from all hierarchical layers of the organization and every discipline that somehow related to the processes. This of course raises the question whether the research data have not been biased by a deliberate selection of interviewees, based on a certain mindset or conformance to the organization's policy. Although this risk cannot be completely excluded, the researchers believe that no purposeful bias has been introduced by the method of selection. One of the strongest indications supporting this belief is the observation that during the interviews the interviewees appeared to very open about their work and in some cases were very critical about certain aspects of it (Smals, 2006, p. 50-51).

All interviews were recorded by means of an electronic tape-recorder with explicit consent from all the interviewees in our sample. This allowed the researchers to fully concentrate on and participate in the interviews themselves. Taking notes during an interview can severely slow down the pace of the conversation, ultimately leading to stagnation of the conversation and thus negating the benefits of a semi-structured interview.

5.3.5 Interviewing style

The interviewing style could be described as colorful and provocative. We adjusted our style to the respondent's language, worldview, professional experience, personality etc. We used statements, dichotomies, metaphors, relied heavily on examples and anecdotes, called on the interviewee's imagination to find out the bottom-line. In this sense we also used a combination of the value focused thinking (Keeney, 1992;1996) and laddering (Rugg, Eva, Mahmood, Rehman, Andrews, & Davies, 2002) technique by asking '*why-why-why*' instead of '*what-why-how*' (Muhren et al., 2008a;Muhren, Van Den Eede, & Van de Walle, 2009;Muhren et al., 2009;Muhren et al., 2009). Reference literature (Saunders, Lewis, & Thornhill, 2000) warns for two types of bias: interviewer bias and respondent bias. The former bias emerges when the interviewer influences the respondent through verbal and non-verbal behavior or through the way of asking questions. For instance, by imposing his/her own frame of reference upon the respondent, the interview outcome is colored. The latter bias emerges when the information provided by the respondent is distorted by his/her ideas on the interviewer, by sensitivities regarding some aspects of the interview items or by a lack of willingness to participate in a time-consuming interview. These are caveats we have taken at heart during our interview sessions.

5.4 Interview analysis

Our research attempts to combine two main approaches in the social sciences. The first of these is to analyze interview data as qualitative data; that is, a transcription of the actual words used by the interviewee, through the technique of cognitive mapping. This verisimilitude is the key attraction of qualitative analysis (Wallace et al., 2003, p. 589). However, this advantage could also be seen as a disadvantage, in that the (comparatively) unstructured data produced are so resistant to procedural, ordered analysis. The quantitative approach, on the other hand, has the overwhelming advantage of producing data that are amenable to statistical analysis, something that is particularly important in a safety context (Wallace et al., 2003, p. 589). Therefore, we take a double approach to interview analysis. We first describe cognitive mapping (5.4.1), subsequently we depict what we have come to call the '*diabolo*' technique (5.4.2).

5.4.1 Cognitive mapping

The recorded interviews were transcribed in the form of cognitive maps. Eden (2004) defines a cognitive map as: *[…] the representation of thinking about a problem that follows from the process of mapping. The maps are a network of nodes and arrows as links [...]*. Cognitive maps form a tool for researchers to visualize how humans within organizations make sense of their environment and thus are helpful in the process of problem structuring in general (Montazemi & Conrath, 1986). Cognitive mapping is a set of techniques for studying and recording people's perceptions about their environment. These perceptions were recorded graphically in the form of a mental map that shows concepts and relationships between concepts. Each individual interview has been transformed in an individual cognitive map, and if desirable all individual cognitive maps could be combined into one aggregated cognitive map representing the way operational risk concerning Incident Management is perceived. Such structuring of data is essential in the process of gaining understanding of the incident management (Bank) and the Maintenance & Repair (NPP) process within its complex environment (Eden, 2004). This general methodology was previously used in similar research (Rutkowski et al., 2005).

Working with cognitive mapping has the advantage that it can bridge the perception of the individual interviewee and the perception of the unit of analysis as a whole. The appropriate composition model for organizational culture is the referent-shift consensus model (Glisson & James, 2002, p. 771). It uses individual responses to measure culture in work-units (e.g. in teams, divisions, departments or organizations). The respondents are asked to describe the behavioral expectations and normative beliefs of people in the respondent's organizational work unit (Glisson & James, 2002, p. 771). Noteworthy is that "*the focus is on what the individual believes are the expectations and norms for the people in the respondent's work unit rather than on what the individual respondent thinks is expected of him or her personally. Within-group consensus is then required to justify the aggregation of the individuals' beliefs about the behavioral expectations and norms within the work unit as a representation of the unit-level construct, i.e., culture. In the absence of within-group consensus, the individual responses cannot be 'composed' to the unit-level construct because a lack of consensus suggests that common expectations and norms have not been identified*" (Glisson & James, 2002, p. 771). Whenever in this dissertation we are interested in finding out how the culture or structure of the organizations under study is contributing to high reliability – and even though we are examining the perception of individuals – we should not focus on the appreciation of the individuals personally, but on their idea about what their team members might think. Therefore, this calls for the application of the referent shift consensus model (Knight, 2004, p. 9).

In order to create the cognitive maps, the interviews with the employees were tape-recorded, to be transformed into cognitive maps afterwards, using Decision Explorer™ from Banxia™ (www.banxia.com). This approach allowed the researchers to capture the interviews in full detail without the disadvantage of having to take notes during the actual interviews.

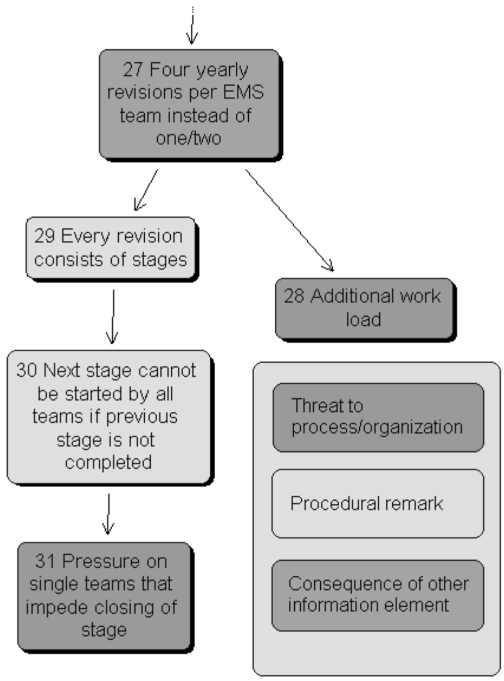

Figure 3.7 - Example excerpt of a cognitive map with categorized nodes

The nodes in the cognitive maps were categorized by coloring them in order to allow for easier analysis of the information stored in them (Figure 3.7). An important category is that of threats to the Maintenance & Repair process or the entire organization that can be recognized in the maps. Nodes directly indicating such a threat were colored red. All the 'red nodes' from the maps were then assembled into an extensive list, from which double entries were removed, while the remaining threats were categorized in order to create an orderly list.

Once completed, the cognitive maps were sent back to the interviewees, giving each of them the opportunity to comment on their personal map and to indicate if they thought the map reflected the conversation as it had taken place. In about eight cases, minor changes to the maps were proposed, adding nuance to certain points. None of the interviewees suggested major changes in the structure of their map. It can therefore be concluded that the cognitive maps accurately represented the course of the interviews.

5.4.2 Diabolo technique

The systems view we take in this dissertation is an alternative for analysis. The accompanying risk is that by breaking things down into smaller pieces to simplify the study, the researcher might lose the oversight and will be developing a less than complete understanding (Bellinger, 2008b). However, we believe that 'anasynthesis', the combination of both techniques, i.e. analysis and systems thinking, is useful. This is exactly what we have tried to do in our research.

To this end, this first research phase wished to determine how HRT – through the characteristics of HROs – could be applied in the particular organizational context of an important economic sector like Banking. Based on the outcomes of semi-structured interviews and workshops with process stakeholders/participants, the researchers gathered a list of operational risks concerning the IM process (Van Den Eede & Van de Walle, 2005). This outcome had to be formulated as an advice – for which there is a shared ownership – to senior management on how to manage risks concerning Incident Management. The approach is not to do this on an operational one-by-one basis, but from a tactical or strategic management, more high-level perspective. Worthwhile mentioning is that it was the Bank's management itself that chose to use HRT as a framework of analysis. Their interest for HRT was inspired by presentations and proposals the authors provided and – more importantly – by accepting the importance of culture, communication, structure, decision making and leadership as a complement to their IT governance frameworks and procedures (De Haes & Van Grembergen, 2005;De Haes & Van Grembergen, 2006).

The analysis is based on a systematic approach that aims at drawing qualitative conclusions from the data. By regrouping and looking for relevance, recommendations for the management of the risks could be formulated. Also has been possible to formulate questions for future research.

In a first phase we have been diverging (risk identification), followed by converging (complexity & tight coupling) to end up again with diverging (tools). We have labeled this the '*Diabolo*' technique (Figure 3.8) and distinguish between the Converging and Diverging capacity.

The diabolo model starts from the assumption that interactive complexity (*C* in Figure 3.8) (complex vs. linear) and tight-coupling (*T* in Figure 3.8) (tight vs. loose coupling) constitute the two major determinants of reliability. For the underpinning thereof, we refer to Chapter 1 – Introduction). In the converging (left hand) part of the diabolo, all the individually identified risks (from the individual interviews) are first aggregated and categorized. With the collaboration of the IM process owner the data have been cleaned (removal of double entries, irrelevant information) and categorized. From the original list of 384 entries, a list of 219 remained. The categorization helped the researchers to gain a better insight into the data and to see the threads in the results. Next, this categorization was used to regroup the 219 records into 42 summarized risks in a meaningful way. Notably these 42 aggregated risks form the basis of the present investigation, which consisted in mapping them on the HRT framework.

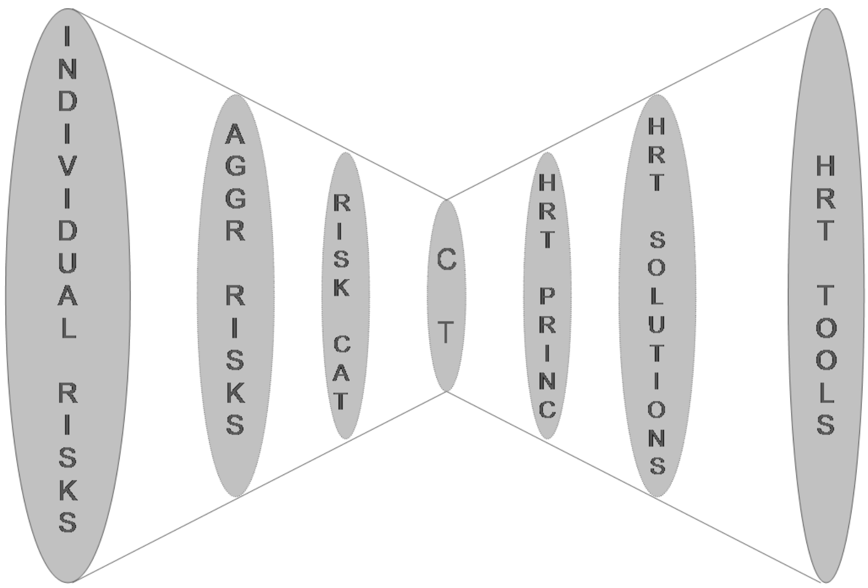

Figure 3.8 - Diabolo Technique

In the diverging (right hand) part of the *diabolo*, the exercise was performed to come up with tools that are typical of an HRO's pursuit of reliability. As a next step, we therefore have mapped the issues to the HRT principles. Subsequently, we have transposed these findings to HRT techniques that are suggested by HRO literature to be proficient in managing risk.

5.5 GSS Workshop[50]

Socio-technical systems such as these are characterized by interactive complexity and tight coupling of risks, and therefore become systemic. Since the source of systemic risks often resides in the unpredictable interactions amongst different parts or components, it is not sufficient to control or mitigate the 'top ten' risks by periodical review meetings based on group consensus (Carlo et al., 2004). In order to improve the management decision process of systemic risks, a shared consensus based on an exhaustive set of potential risks and their interrelations has to be socially constructed (Rutkowski, Van de Walle, & Van Den Eede, 2006). Moreover, we assume that the parallelism, anonymity and the voting provided by a Group Support System (GSS) environment would efficiently support such a task.

In past laboratory and field research, GSS have proven to efficiently facilitate preference and intellective tasks via anonymous exchange of information supported by an electronic brainstorming system (EBS) and to reduce process losses inherent to face-to-face meetings (van Genuchten, van Dijk, Scholten, & Vogel, 2001;Nunamaker, Vogel, & Konsynsky, 1989). The workshop used GroupSystems™, a software from GroupSupport.com, was used to support the exchange of information among staff. GroupSystems™ is a facilitator driven group decision support system (GDSS) that can be used to carry out a variety of strategic management and decision-making processes effectively and with high levels of group participation, ownership and commitment. The individual participants were able to anonymously enter their ideas on their personal computers, which were all connected by means of a local area network to a central computer, from which the output was projected on a publicly visible space using a data projector. A key benefit of using this GDSS can be a more efficient use of meeting time, through the ability to surface and 'parallel process' more contributions from a greater number of participants than is possible using manual facilitation techniques alone. At the Bank 19 staff and at the NPP 12 staff that were involved with the incident management process were invited to join a GroupSystems workshop (February 2005 and April 2006 respectively), for which the author has acted as facilitator. The purpose of the workshop was to decide on the risk identification, risk assessment and risk control measures. The result was an advice – for which there is a shared ownership – to senior management on how to manage risks concerning Incident Management.

The advantage of anonymous data entry by the individual group members is that sensitive issues can be more easily brought into the open and discussed objectively without fear of reprisal.

Each of the workshops was organized as follows:

Phase I — *Brainstorming* phase (Electronic Brainstorming Risks or EBS): The outcome of the previous research phases (interviews and aggregated cognitive maps) constituted the input for the GSS workshop. The categorized threats were presented to the participants (of which some were interviewed previously), who were asked to anonymously add comments and add threats they felt were missing in the presented list. Based on idea exchange and free association, the participants were proposed to generate an exhaustive set of risks based on and departing from the compiled list of risks.

Phase II *Intellective* phase: Individual selection of the most relevant top risks following 'truth supported wins' schemes of decision.

Phase III *Preferential* phase: Assessment of the selected risks during phase II in term of Expected Utility. To this end, the participants were asked to rate each threat on two scales: impact and likelihood. The most relevant risks have been discussed to build scenarios that can be activated through the formation of a group memory when the risks actually materialize.

Special attention was given to the efficiency of the GSS on the preference and selection of three type of risks: Common Risks (CR) and Unique risks (UR) presented under the form of a list based on individual interviews on the one hand, and socially constructed risks generated during the brainstorming phase on the other hand. The fact that the participants of the GSS workshop provided information that was already present in the data gathered from the interviews illustrates the use of GSS as a tool to confirm the validity of previously gathered research data. An additional benefit of the use of GSS was the possibility provided to the participants to elaborate on specific problem areas (Smals, 2006).

We believe the management of the decision process of systemic risks can be improved by co-evaluation and an objective measure such as Expected Utility. Shared consensus based on an exhaustive set of potential risks and their interrelations have to be socially constructed and – when relevant – the unique information of the minority surfaces the collective iceberg. The results of the research demonstrate that the parallelism, anonymity and the voting provided by the GSS environment efficiently supports the task of risk management decision process in a spirit of socially shared consensus.

GroupSystems increased overall the level of awareness amongst the participants on the importance of addressing risks in the organization. The large number of risks that were generated using the system gave a better understanding to the participants about the situation. The anonymity and the interview phase were two critical success factors. First, anonymity supported participants to express freely their private opinion about very sensitive information in the organization. Second, the risks of lists being a mixed of unique, common and EBS risks, the expression of the participants' preference gave to the group of the participants a higher feeling of control and appropriation of the decision taken toward the scenario to be built.

In the sense that this GSS workshops are a type of focus group, its outcome co-formed the basis for the development of a questionnaire (Yule, 2003).

The resulting rankings showed two particularities: firstly, there was little scatter in the ranking of the top-rated threats; on a scale from zero to seven (zero representing a high likelihood respectively high impact), most assessments of both impact and likelihood were between three and five. The limited spread resulted in a rather flat distribution, delivering a quite large portion of top-rated threats: 32 out of about 230 threats were deemed of special importance, although these top-rated items were not on a large distance of the less relevant threats in terms of impact and likelihood. Secondly, 10 out of the 32 top-rated threats were not present in the list that was extracted from the cognitive maps.

The issues added to the list of threats during the session were subjects that were implicitly present in the cognitive maps and had been recognized by the researchers, but only those threats that were explicitly mentioned during the interviews and categorized as such were included in the list. For example, the highest-ranking threat was labeled ‘workload increases while the number of qualified employees decreases’. This threat was not in the list of threats extracted from the cognitive maps, but was added by the participants during the group work session. Although no node with the exactly matching content was present in the cognitive maps, several nodes conveyed parts of the same problem. For example, in the cognitive maps, constructs were present describing the increase of work pressure, the retirement of the current generation of experienced workers and the difficulty of attracting highly qualified workers to replace the older generation of employees.

5.6 System dynamics modeling

5.6.1 Application

The outcome of the previous research phases formed the input for a system dynamics modeling exercise we undertook to model the reliability of the organization’s Incident Management process as determined by the capability of its supporting emergency response information system (Van Den Eede, Muhren, Smals, & Van de Walle, 2006). This work is based on the Capability Trap model by Repenning & Sterman (2001) and draws from the many insights on emergency response information systems design as described in the DERMIS (Dynamic Emergency Response Management Information System) framework established by Turoff et al. (2004). Whereas the latter authors describe the premises that underlie an Information System (IS) that is capable of ensuring a reliable and flexible emergency response, our model contributes to the research field by looking at the interrelations of the aforementioned premises. We take a System Dynamics approach and gain insights in the key determinants of IS Capability by highlighting the mutual interdependences grouped around the concepts of adaptability, control, implicit knowledge and explicit knowledge. The following sections subsequently explain the technique (5.6.2) and the need of system dynamics for studying HROs (5.6.3).

5.6.2 System dynamics

System Dynamics was developed by Jay W. Forrester (1961) during the mid-1950s at the Massachusetts Institute of Technology (MIT). It is a method to gain insight – i.e. identifying, explaining, and eliminating problem behavior (Marais & Leveson, 2003) – into the behavior of (especially socio-economic) complex systems over time and enhances learning from these complex systems (Sterman, 2000, p. 4). Principally by identifying feedback loops in the system, it provides a framework for dealing with dynamic complexity, where cause and effect are not obviously related. System dynamics is grounded in the theory of non-linear dynamics and feedback control, but also draws on cognitive and social psychology, organization theory, economics, and other social sciences (Marais & Leveson, 2003). It does so by representing the processes, structure, strategies and information flows of systems (Wolstenholme, Henderson, & Gavine, 1993).

Forrester (1993) states that all decisions are made in an on-going circular environment in which each action is based on information that is the result of earlier actions. System dynamics is based on the idea that people cannot oversee the consequences of these feedback mechanisms in complex systems. There is a bias of looking for problem causes in convenient places (Moberg, 2001). "*[There] is a fundamental characteristic of complex human systems: 'cause' and 'effect' are not close in time and space. […] Why is this a problem? Because most of us assume, that cause and effect, most of the time* are *close in time and space*" (Senge, 1990, p. 63). Therefore, much of the art of system dynamics modeling is discovering and representing the different feedback processes in a system (Sterman, 2000, p. 12). A System dynamics model is meant to give people a more effective understanding about an important system that could have controversial behavior. Influential system dynamics models are those that change the way people think about a system (Forrester, 1993). Wolstenholme (2004) distinguishes five components of system 'structure' in the concept of system dynamics: (1) processes, created using stock-flow chains; (2) information feedback; (3) policy; (4) time delays; and (5) boundaries.

5.6.3 The need of system dynamics for studying HROs

System Dynamics has been applied in all kinds of domains and for all kinds of problems, like the cold war arms race, the human immune system, the aircraft industry, and business and strategy issues (Sterman, 2000, p. 41-42) but the technique can play an equally important part in the study of High Reliability. We posit that HRO literature can do with more system dynamics exercises. In our case, for instance, by building an explicit representation of the incident management process, it should/might be possible to predict, simulate, and/or explain the resultant behavior of the system form the structure causality, functional and behavior of its components (Lewis, 2004). "*If we do establish a connection between given features of an organization and its operational reliability, can we assume that these features are necessary, rather than merely sufficient? That is, are there alternative strategies possible for the production of the same outcome, or do the requirements for organizational reliability impose an inevitable solution on an organization? Finally, even if an organization has evolved features that are necessary to its reliability, can we be sure that its evolutionary adaptation is stable, that what adds reliability today will also work tomorrow under changes in the character of technology, the work force, or in the life cycle of the organization?*" (Schulman, 2001, p. 347-348). Hence, this is a useful approach to deal with non-linear problems in a non-linear way (contrary to a classical risk management approach). While it is tempting to attribute the kind of reliability described in this dissertation to organizational culture and values (Little, 2005, p. 5) it is not sufficient. What we need is a laboratory setting that permits to verify independently the different building blocks[51]. System dynamics modeling is a relevant technique for our research because of the complex nature of the emerging interactions (i.e. complexity), the choice of our model is vital.

Efforts to model HRO characteristics so far have mainly concentrated on unreliability, in studies of calamities and mishaps: for instance, the 1992 Westray mine disaster (Cooke, 2003), the 1986 Chernobyl nuclear disaster (Salge & Milling, 2006). In part this is due to the prescription that system dynamics should model problems, not systems (Sterman, 2000), but such can be remedied by formulating high reliability as a problem, e.g. by modeling the absence of HRO characteristics and investigating the consequences thereof on organizational reliability. Examples of application of system dynamics in HRO contexts include (for instance) outage planning and plant improvement efforts and maintenance (Caroll, Perin, & Marcus, 1993); patient safety (Cook & Rasmussen, 2005); security incident management (Gonzalez, 2005) and railways safety (Hale et al., 2003). Notable studies building on system dynamics for conceptualizing on HRO and NAT include the analyses by Cooke & Rohleder (2006) and Rudolph & Repenning (2002).

The latter type of studies is interesting because they have the potential of combining system and culture, as "*the two great tropes of the 20th century […]. Whereas systems thinking holds out hope for the precise mapping and managing of complexity, cultural approaches are less focused on outcomes and more on understanding and appreciating the meanings people ascribe to collective behavior, and how these meanings help constitute communities and societies*" (Eisenberg, 2006, p. 1697). For instance, Romme and van Witteloostuijn's (1999) notion of 'circular design' combines (1) insights from Organizational Learning Theory with (2) insights from Systems Theory. More specifically, they combine the concept of triple loop learning, manifesting itself in the form of 'collective mindfulness' with three important notions of system dynamics: (a) the pervasive influence of the deeper structure of a system on the behavior of its constituent elements; (b) the difference between static and dynamic systems; and (c) the dilemma between global patterns (e.g., corporate patterns and synergies) and local behavior (e.g., creative actions and findings at the unit or team level). The analysis of circular designs relates strongly to the HRT concepts as it also examines the relationship between structure and behavior. More in particular, circular design, like HRT, stresses the importance of the opportunity to switch between the circular and the hierarchical mode of organizing, as a pivotal element (Romme & van Witteloostuijn, 1999).

6 Survey

Without prejudice to the relevance of the previously described research techniques (5.3 to 5.6), this research's main data collection technique is a self-administered survey. For this reason this separate section is dedicated to its description. The survey questions respondents in our case study organizations on those elements that have become apparent in the previous research phases. In this subsection we first point out why we have chosen for the survey technique (6.1). Next, we explain the way the conceptual model is operationalized (6.2) and how the survey is administered (6.3). We conclude this section with a description of the data analysis process (6.4).

6.1 Rationale

In an era where '*what cannot be measured, is not true*', a particularly difficult task emerges to translate constructs like mindfulness and resilience into workable indicators (Le-Coze, 2006, p. 8). As we have experienced ourselves, this exercise is necessary in order to get stakeholder's – and especially management's – commitment to cooperate. The *buy-in* [52] is obtained more easily with figures. The survey we have designed hence is a mixture of trying to measure the immeasurable and returning value for money. We have tried to find our way out of this dilemma by gaining trust of the organization by doing 'consultancy' jobs of a smaller order.

The use of quantitative research techniques in the field of organizational behavior is not very common (Balthazard & Cooke, 2004, p. 240). Qualitative and quantitative methods nevertheless are complementary approaches to the study and assessment of organizational processes and attributes. The advantages of qualitative methods can lead to intensive and in-depth information, especially useful in research on issues and processes about which little information exists (Balthazard & Cooke, 2004, p. 240). Quantitative methods on the other hand have the advantage of cross-sectional assessments and comparisons (across individuals, organizations, or sub-units). It is this last characteristic we have relied on since we deal with the phenomenon of an organization's reliability through its subunits as level of analysis. A greater understanding of the factors and values that affect intra-organizational contextual and structural variations can only provide an even richer picture of how to optimize organizational systems to promote reliability (Balthazard & Cooke, 2004, p. 240).

Quantitative methods facilitate asking large numbers of people their opinions in a relatively time- and cost-effective manner (Child & McGrath, 2001). It should not come as a surprise therefore that over the years, the survey method was extensively used and is still in predominant use. While the method can attain high levels of external validity, it is known to suffer from lack of control and internal validity (Palvia et al., 2003). Another critique on surveys in the field of reliability is that they are used merely to refine the question sets in order to improve face validity, and in some cases to conduct factor analyses and internal consistency checks (Child & McGrath, 2001). Yet, quantitative research that goes beyond this type of analysis is necessary in order to bring the discipline of reliability studies to reach a higher level of maturity.

6.2 Operationalizing the conceptual model

A conceptual model of variables and their relationships leads to the formulation of hypotheses. It relates dependent and independent variables and identifies the moderator variables that are likely to affect the outcomes. Essential in conducting research in organizations is assuring the accuracy of measurement of the constructs (Hinkin, 1998, p. 104).

6.2.1 Item generation

Although literature is readily available, quite rare are the practical translations of theoretical concepts into straightforward guidelines for measuring the degree of high reliability or SenseMaking. Moreover, when publications do get practical, they are concerned with safety, not reliability. The only notable exception being Weick and Sutcliffe with their 'Managing the Unexpected' (2001). These authors offer ways to materialize theory by means of High Reliability audit check-lists (Weick & Sutcliffe, 2001, p. 90-110). We have gratefully used this material to build our own questionnaire. For SenseMaking the job was even harder. Probably because of the opaque nature of this set of notions, to the best of our knowledge, no practical translation could be found. For these reasons, we had to rely on interpretation of literature and above all, on the outcomes of the analysis of the interviews. These formed a cornerstone for the development of the 'High Reliability Questionnaire' (as we have come to call this survey) for the Bank (Appendix D) and for the NPP Case (Appendix E). The interviews were essential in customizing the constructs for the setting of the Bank as well as the NPP. Both questionnaires are identical apart from an adjustment to comply with specific process attributes and jargon.

The items were generated in such a way that they adequately represent the constructs (Hinkin, 1998). We have taken a deductive scale development approach since the theoretical foundation provided enough information to generate the initial set of items, founded on a thorough review of the literature (Hinkin, 1998, p. 106). Items were developed according to the following guidelines: (1) Statements that are as short as possible, (2) Language as simple as possible, (3) Addressing one single issue per item, and (4) No reverse-scoring. At least four items per scale are needed to test the homogeneity of items within each latent construct, yet adequate internal consistency reliabilities can be obtained with as few as three items (Hinkin, 1998, p. 109). Scales with many items may have high internal consistency reliabilities even if the item inter-correlations are low, an argument in favor of shorter scales with high internal consistency. The retention of four to six items for most constructs therefore is advisable (Hinkin, 1998, p. 109). It is also good practice to foresee twice as many items in the survey questionnaire.

The survey consisted of 57 variables. As we had the data on the Incident Management reliability on team level, we had to aggregate the data of the individual respondents on team level as well. In order to correct for teams with an insufficient number of members participating in the survey, we put a double filter on the data. We selected teams that met one of the following criteria: at least 5 participants in the survey or at least a participation rate of 50%. This double criterion could only be maintained for the Bank Case. The NPP Case consisted of too few respondents to do so. In case of the NPP Case a preference was given to having a sufficient number of teams.

All items were measured on a 5 point Likert scale and with respondents being asked to indicate whether they fully agreed (5), agreed (4), agreed, nor disagreed (3), disagreed (4) or fully disagreed (1) with the statements presented to them. The choice for a 5 point Likert scale is inspired by the fact that coefficient alpha reliability has been shown to increase up to the use of five points Likert scales, after which it levels off (Hinkin, 1998, p. 110).

6.2.2 Constructs

A construct is a representation of something that does not exist as an observable dimension of behavior, and the more abstract the construct, the more difficult it is to measure. A construct should meet the following criteria in order to assure construct validity (Hinkin, 1998, p. 105):

(1) Content validity, i.e. specifying the domain of the construct;
(2) Criterion validity, i.e. empirically determining the extent to which items measure the domain;
(3) Internal consistency, i.e. examining the extent to which the measure produces results that are predictable from theoretical hypotheses.

These requirements have been taken into account when developing our items (statements and questions that form the constructs). The constructs usually employed in research on organizational culture are of no immediate use for the study of High Reliability because they are too general and too distant from the functional imperatives of reliability enhancing organizations (Klein, Bigley, & Roberts, 1995, p. 773). Chapter 4 shows that the variables employed in our study therefore are somehow different from traditional studies on organizations.

The independent variables in the (reconceptualized) model relate to the constructs of (1) HRT propensity and (2) SenseMaking propensity. By propensity, we mean the natural tendency to behave in a certain way. In the case of HRO propensity, it therefore is the natural tendency to behave and to be structured like an HRO. As such, it is a tendency towards HRO-like behavior and HRO-like structure. It is the degree to which an individual, a team, or an organization fits the HRO ideal such as it is described in literature. SenseMaking and efficiency propensity can be defined in the same way (*mutatis mutandis*). All constructs are examined in relation to the incident handling process. In the a priori conceptual model, there is one moderator variable, namely the alignment of information systems to user characteristics (ISFit) (3) In the reconceptualized model, two additional mediator variables are introduced, namely Requisite Variety (4) and Structure (5). The dependent variables are the reliability in the handling of urgent and non-urgent incidents respectively (6). They are calculated values retrieved from the organization's incident management databases.

6.3 Survey administration

6.3.1 Pilot

In view of content validity assessment, we have subjected our items to an assessment in two phases. In a first phase, we have pretested them with a group of experts (from academia and practice) and have asked them individually to attribute the items to the constructs in question and to eliminate those items that in their opinion did not cover the constructs. In a second phase, we have pretested the remaining items with two pilot groups of respondents from our population (Pilot Bank Case and Pilot NPP Case). The outcomes of this pretest were on the level of language clarity, jargon utilization, team identification, the practicality of the questionnaire design (e.g. the use of drop-down boxes) and seven items that were dropped because of their inappropriateness.

In the Bank Case, the first pilot survey consisted of six Information Security Officers (ISO) at the Bank. This survey has been administered as an MS-Excel file. The second pilot (Table 3.10) consisted of four incident management teams, selected from our population based on their representative character. This second pilot survey has been administered via CheckMarket™, the platform that has been used for the final survey.

Descriptors	
Average fill-out time	15 min. 33 sec
Panel size	35
Number of respondents (completed)	27
Number of teams	4
Reminders	14 (40%)
Resminder response	7 (50%)

Table 3.10 - Pilot descriptors for the Bank Case

The full questionnaire was administered electronically: online through the company intranet in the Bank Case and via e-mail in the case of the NPP. In each case study, a pilot survey was conducted to test the questionnaire prior to the administration. Electronic surveys have distinctive technological, demographic, and response characteristics that affect their design, use and implementation (Smith, 1996). Although it is advisable to compensate by 30% the number of respondents for non-response so that the power of the survey (i.e., precision and confidence level) is not compromised (Kasunic, 2005, p. 27), we were only able to do so in the Bank Case.

6.3.2 Distribution

Running a survey is taking a snapshot of an organization at a certain point in time. In the Bank Case the period during which the survey was applied was June 21st - 30th 2006. The survey was announced by a personalized e-mail invitation, addressed to the organization mail account of the team members, containing a click-through link to an external server, hosted by CheckMarket™ (http://www.checkmarket.be), an online platform that provides tools to securely create and distribute online surveys. Anonymity has been guaranteed. In the Bank Case this could be done because no track was held of a the respondents who actually filled-in the survey.

In the NPP Case, we relied on a self-administered questionnaire in the period Sept 17th - 30th 2007. The survey was announced by a general e-mail invitation, addressed to the account of the team members, containing an attachment with an excel survey form. This form contained some Visual Basic Coding in view of ease of use for the respondent and the research analyst. The respondent was asked to return the attachment to the researcher. Note that unlike with the Bank Case, the survey in case of the NPP was not administered through a professional platform like CheckMarket™, but through a self-developed data collection tool. As a result some of the benefits of the former system could not be seized in case of the Bank. For instance on the level of quality control it was impossible to control on the time a respondent spent on filling out the questionnaire. More important is that for the same reason anonymity could only be guaranteed partially: The anonymity from the respondent to their organization could be guaranteed, but not towards the researcher.

6.3.3 Population and sample

In the Bank Case the research population consists of all the teams (and their members) that have been involved during the period January to December 2005 in incident handling (in whatever role or function) and that had a minimal average of 1 urgent incident (urgency 1 or 2) per month.

This threshold has been built-in to guarantee that it reasonably can be assumed that the teams are familiar with the handling of urgent incidents. We wanted to avoid that urgent incidents would have the status of ‘exceptional’ because that would mean that they are not representative for the work of incident handling. In the Bank Case, because we have chosen to study five critical business domains (Assets, Payments, Accounting, Trading, and Markets) and their corresponding IT processes, the vast majority of teams are in the situation of being familiar with the handling with urgent incidents. This yielded a list of 69 teams consisting of 602 theoretically corresponding e-mail addresses, representing an equal number of team-members. Of the 602 invitation e-mails 41 bounced back indicating that these addresses were fictive or did not longer exist. Two respondents declined the invitation to open the e-mail. The number of people that were reminded (after 7 days, so June 28th) to fill out the survey was 243, of which 84 responded to the reminder. In total, a 477 people read the e-mail, from which 404 clicked through the questionnaire. A total of 399 persons answered the questionnaire, of which 356 answered the questionnaire from beginning to end (except for an occasional blank question). From this cleaned dataset [53] of 356 respondents, those respondents filling in a management position were left out of the analysis because it was presupposed that they would be not representative for a team's HRO profile. This impacted the final sample size (n= 320) only moderately.

Similarly, in the NPP Case, the research population consists of all the teams that have been involved during the period September 2006 to August 2007 (included) in the Maintenance & Repair Process and that had a minimal average of 1 incident of urgent notifications and orders (priority 0, i.e. urgent notification). This in order to guarantee that the teams under study are familiar with urgency (cf. Bank Case). The number of staff that has been selected (at random) was 213.

6.4 Data analysis

In the Bank case the number of respondents was 320. In the NPP case the number of valid responses was 124. These sets formed the basis for further data analysis, which was performed primarily by means of SPSS 15.0 for Windows.

6.4.1 Data reduction

To reduce the dataset into a set of less and more meaningful constructs, we conducted an exploratory factor analysis and measured the internal consistency of the emerging factors. Factor analysis allows the reduction of a set of observed variables to a smaller set of variables so that a more parsimonious representation of the original set of variables is obtained. The objective is to identify those items that most clearly represent the content domain of the underlying construct (Hinkin, 1998, p. 112-113). This approach has the one advantage over a pure inductive item generation that it builds on existing theory where possible, so that the factor analysis better guarantees construct reliability: The inherent risk of the inductive method that although items may load on the same factor without necessarily measuring the same theoretical construct therefore is mitigated (Hinkin, 1998, p. 107). We used a principle components analysis with a varimax rotation to examine their underlying structure. A .40 criterion level was used in judging factor loadings as meaningful (Koch, 1993) and a 60 % level of the total item variance that is explained by the factors (Hinkin, 1998).

In our choice of the factors we have selected for building our conceptual model(Table 5.1), we have been lead by those factors that had a sufficient internal consistency (Cronbach's alpha ≥ 0.60).

6.4.2 Scale validation

As described in the previous chapter, many of the hypotheses in our conceptual model are based on composite variables (scales) comprised of different items (questions). Before testing hypotheses, each of these composite variables or scales should be validated, to assess their level of internal consistency of reliability. Two important types of validity in survey research are (Kasunic, 2005, p. 12): (1) construct validity: Are we measuring what we think we are measuring? and (2) external validity: Can the results be generalized to other people, places, or times?

We use Cronbach's Alpha for the estimation of the former validity, the internal consistency reliability. Internal consistency reliability is the degree to which an instrument again and again measures an attribute. A large coefficient alpha suggests that the sampling domain has been captured adequately (Hinkin, 1998). In this research, a scale will be considered reliable only if a Cronbach's Alpha Coefficient of 0.60 or greater is found. In those cases, the item scores used to create the scale can be aggregated and analyzed for statistical significance to test the corresponding hypothesis. In order to improve the Cronbach's alpha coefficient, and in those cases where the number of retained items was sufficiently large, those items were eliminated that that will improve or not negatively affect the reliability of the scales (Hinkin, 1998).

6.4.3 Analysis of Variance

In a first approach we followed Klein et al. (1995) and performed F-tests, one way analyses of variance and regression analyses to test differences and similarities across and within organizations. This approach however did not yield any significant results and this way of analyzing was abandoned and omitted in this dissertation. To test the hypotheses put forth in the previous chapter, General Linear Model (GLM) Repeated Measures Analyses of Variance are performed, which is an extension of the analysis of variance technique (ANOVA). More particularly for the purpose of our research, we performed Tests of Between-Subjects Effects. The leading idea behind this technique is the assumption that there are systematic differences between groups, in that sense that these groups show averages in the population that differ. These differences are to be discovered on the basis of a sample of observations (van den Bercken & Voeten, 2002). The term 'repeated measures' refers to multiple observations of either exposure or outcome on the same sampling unit, in our case a team. Often these observations within the same subject will be correlated and this has to be taken into account when analyzing such data. Whereas this is reported as a problem inherent to the use of the repeated measures technique, in our research this constitutes an advantage. Reliability can be defined in several ways, one of them being the reduction of variance in reliability outcomes, and therefore it is useful to see the pattern between reliability observations within a time interval.

For the purpose of the analysis of variance, categorical variables needed to be created from continuous scale variables. By means of *Visual Binning*, we created new variables based on grouping values of existing variables into a two distinct categories. The median was used as a cut-point with border values included in the lower category.

As we have the data on the IM reliability on team level, we had to aggregate the data of the individual respondents on team level as well. In order to correct for teams with an insufficient number of members participating in the survey, we put a double filter on the data: we selected teams that had (1) at least 5 participants in the survey or (2) at least a participation rate of 50%. The application of these selection criteria resulted in 37 teams for the Bank Case and 24 teams for the NPP. Even though the original data set yielded 320 valid and selected respondents in case of the Bank and 128 in the case of the NPP, the small sample sizes on the aggregated level (37 (Bank) and 24 (NPP) teams) has the disadvantage of a lower probability of showing significance in an ANOVA. Therefore, we are convinced that the lack of a bigger sample requires a more flexible statistical significance level for our analysis. Instead of the common statistically significant p value ≤ 0.05, we worked with the practical significance of $p \leq 0.10$. In line with Ferguson and Ketchen (1999, p. 387) we have chosen to include in our analysis levels of analysis of up to 0.10 because HRT is still not developed enough to allow for a more precise test, in contrast to theories that can build on much wider established body of quantitative research where a level of 0.01 would be more appropriate.

7 Conclusion: Build-up and Hermeneutic Circle of Understanding

Throughout the research, we have made an attempt at connecting data and theory while relying on the research taxonomies enlisted above and while relying on a wide range of techniques. Their development is depicted in Table 3.11. The research methodology alternates between positivist and interpretive, between normative and descriptive, between deductive and inductive, between quantitative and qualitative. Individually, these lenses are valuable for analysis (deduction) but their true value lies in their combination in form of new constructs (induction). In the first case, the observations will be starting point, in the second they will come enhanced out of the process. In this model, observations are alpha and omega, but with the intermediary role of a theory that emerges from these observations. That way, the divide between empiricism and rationalism can be remedied.

Following Butler (1998, p. 293), the concept of the hermeneutic circle of understanding was applied throughout the case studies on the incident management process reliability. Table 3.12 provides a graphical representation of the hermeneutic research process in terms of the hermeneutic circle of understanding. Recall Figure 3.6 showing Gadamer's argument that the unity of understood meaning expands in concentric circles with the letters *A* to (in our case) *I* representing the stages of understanding. Note however, that the actual hermeneutic process is much messier: less concentric, more fanciful and characterized by interruptions.[54] Noteworthy is also that the outer circle most certainly will not be the final outer circle as our understanding will always remain incomplete and challenged by new circumstances.

The apex stone of the hermeneutics underpinning this research is its multiple-case character. Because of the identical research build-up in both our cases, we were capable not only of data-theory triangulating within-cases, but also in between them. This '*twin*' approach is quite rare in HRO research since much of it is still based on individual case studies. Together with Schulman (2001), we deem this inflicts a danger to the discipline: "*in danger of falling victim to a kind of evolutionary optimism that infers that because features have evolved in an organization that is surviving in a high-reliability niche, these features must all contribute to its overall reliability. In research on high reliability in organizations, we are beset by the problem of many variables and few cases. How, without more failures, can we really be sure which of the many organizational features we see are in fact adding to reliability?*" (2001, p. 347). In themselves, these cases provide little evidence that the presence of certain HRO parameters will lead to high reliability. It might even very well be that they have a negative effect on it and that reliability is there despite of them. The twin case study approach hence offers an opportunity of enhancing insights in the nature of High Reliability. A warning is in place however. Formally, the research design is multiple-case but because of the number of cases limited to two, the replication logic, in which the cases are treated as a series of independent experiments that confirm or disconfirm emerging conceptual insights, does not fully apply. The purpose we had with the design of our research has been to compare both cases from the standpoint that the NPP Case should represent what is described in HRO literature, and that we would check whether our findings in the Bank Case would confirm this. For feasibility reasons however, the Bank Case was conducted prior to the NPP Case. This data are analyzed in Chapter 6.

Technique \ *Taxonomy*	**Positivist**	**Interpretive**	**Normative**	**Descriptive**	**Deductive**	**Inductive**	**Quantitative**	**Qualitative**
Literature review (Chapter 2)	x		x		x			x
Case Study Preparation and Documentary Research (5.2.1)		x		x	x		x	x
Action Research (0)		x		x		x	x	
Ethnographic field study (0)		x		x		x		x
Interviews – Putting HRT in a broader spectrum (5.3)		x		x	x			x
Interview Analysis – Cognitive Mapping (5.4.1)		x		x		x		x
Interview Analysis – Converging diabolo (5.4.2)	x			x		x		x
Interview Analysis – Diverging diabolo (5.4.2)	x		x		x			x
GSS (5.5)		x		x		x	x	
System Dynamics Modeling (5.6)		x		x		x	x	
Survey – Exploratory Factor Analysis (6)	x		x		x		x	
Survey – Testing HRT and SeMa Hypotheses (6)	x		x			x	x	

Table 3.11 - Alternation between research taxonomies and research techniques

Circle	*Researcher's Horizon*	*Phenomenon's Horizon*		*Research Technique*
		Whole	*Parts*	
A	Pre-understanding of high reliability mechanisms: the more the better	Incident management process Reliability	HRT constructs SeMa properties	Literature review (Chapter 2) Case Study Preparation and Documentary Research (5.2.1)
B	Crystallizing of the research question: *Can Mainstream organizations be HROs?*	Incident management process	Individual tasks	Action Research (0) Ethnographic field study (0)
C	Re-confirmation: *Mainstream organizations can be HROs.*	Aggregated risk identification and process reliability	Individual respondents view on incident process reliability	Interviews – HRT in a broader spectrum (5.3) Interview Analysis – Cognitive Mapping (5.4.1)
D	Complexity and Tight Coupling are essential insights: *Predominance of NAT over HRT*	Identification of instances of complexity and tight coupling at the organizational level	Identification of instances of organizational complexity and tight coupling at the individual level	Interview Analysis – Converging Diabolo (5.4.2) Interview Analysis – Diverging Diabolo (5.4.2)
E	Validation of the insights from the previous step.	A preferenced, collection of risks seen by the organization as a whole	Individual process view on process reliability	GSS (5.5)
F	*Reliability has its price*	A nuanced view on becoming a HRO	Separate observations of the nuances in high reliability.	System Dynamics Modeling (5.6)
G	*The poison makes the dose*	Aggregattion of HRO en SeMa propensity on team level	Individual respondent's HRO en SeMa propensity	Survey – Exploratory Factor Analysis (6)
H	*HRO and SeMa constructs do exist, but differ from theory as described in literature*	Two-dimensional testing of the HRO and SeMa constructs and team performance	One-dimensional testing of the HRO and SeMa constructs and reliability	Survey – Testing of HRT and SeMa Hypotheses (6)
I	*Moderators have d tremendous impact*	The mutual impact of tight or loosely coupled constructs	Categorization of a coupling's Type, Cause, Direct Effect or Compensation	Loose coupling – Discussion of research findings (Chapter 7)

Table 3.12 - Hermeneutic research build-up (In analogy with Butler, 1998, p. 296)

Chapter 4 Reconceptualization

We all agree that your theory is crazy,
but is it crazy enough?
Niels Bohr

This chapter presents a reconceptualization of HRT. In Section 1, we first address the initial conceptual model derived from the literature reviewed in Chapter 2. As the exploratory factor analysis run on this model did not yield the results that were expected and were in line with what is suggested in literature, we had to (re)introduce (new) constructs into the research design. The outcome of this process is an extension of extant literature on HRT, notably with regard to the Michigan HRO School, and suggests the need for further theory building. For this, we fall back on writings by scholars from the Berkeley School (Section 2). These constructs are discussed in detail throughout the next five sections (Sections 3 through 8). Consequently, we are compelled to reconceptualize our a priori model (Section 1) and to formulate a new set of propositions and hypotheses (Section 2).

1 *A Priori* Conceptual Model Construct Validation

A conceptual model defines the elationships between constructs and variables through the explicitation of propositions and hypotheses (Bacharach, 1989). By analogy with what we have described in the methodology chapter, the basis for our initial conceptual model – henceforth referred to as the 'a priori conceptual model' – is formed by a double assumption. A first assumption is that the literature on high reliability theory – and more in particular the Michigan School – offers a set of constructs that captures the high reliability character of an organization. A second assumption is that this set is exclusive in a sense that the items that are suggested by literature univocally converge into one of the proposed items. These assumptions refer to hermeneutic circle of understanding *G* from Table 3.12. The corresponding conceptual model is shown in Figure 4.1. It regroups three propositions:

P1: A higher HRO propensity results in a higher reliability than a lower HRO propensity.

P2: A higher SenseMaking propensity results in a higher reliability than a lower SenseMaking propensity.

P3: The more the dedicated IS is used for the registration of incidents and the more it is used for the communication during the incident handling, the higher the reliability.

P4: The fit of a team's HRO propensity and the use of the IS determines reliability.

P5: The fit of a team's SeMa propensity and the use of the IS determines reliability.

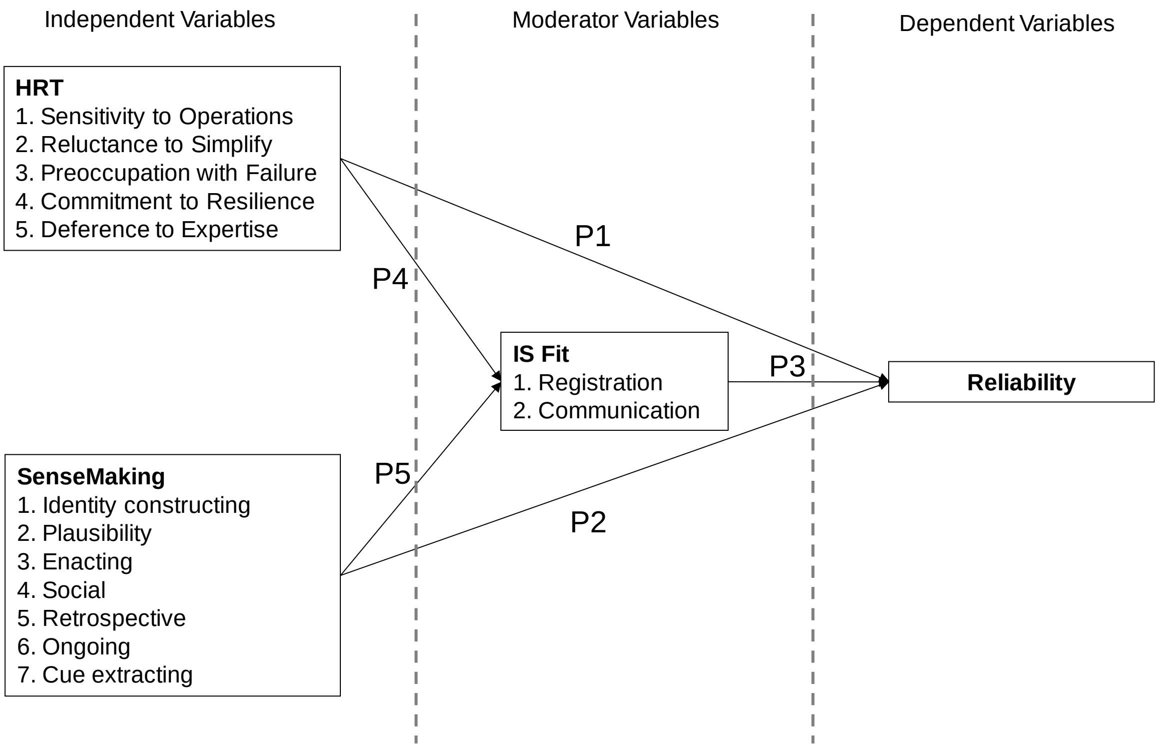

Figure 4.1 - The *A Priori* Conceptual Model

Based on our literature review from Chapter 2, we regroup the items per HRO construct as proposed in Table 0.1 through Table 0.5 in Appendix C. Apart from meeting validity requirements, the characteristics of the factors do not meet the expectations as expressed in Table 0.1 through Table 0.5. Appendix C further learns that KMO parameters and explanation of variance can be considered acceptable. Our conclusion hence is that our first attempt to structure and interprete the high reliability issue in our case studies, relying on literature in the field of HRT and SeMa does not yield the expected results. A comparison of the derived factors with the factors first reported by Weick, Sutcliffe and Obstfeld (1999) does not hold. We recall that these factors are: (1) Sensitivity to Operations, (2) Reluctance to Simplify, (3) Commitment to Resilience, (4) Preoccupation with Failure and (5) Deference to Expertise (See Chapter 2: Literature Review). These constructs were not supported by internally consistent factors in the data. Several factor analyses were carried out in order to fit theory to empiric observations, but the responses to the different items were not the way they had been conceived beforehand. Therefore, sticking to the theoretical constructs as provided by literature on HRT and SeMa is not leading to a workable conceptual model, at least not within the context of our research design and data.[55] For this reason, we decided to let loose the original constructs and start searching for new ones that may be better supported by data.

2 Reconceptualizing the *A Priori* Model

Instigated by the hermeneutic approach described in the previous chapter, we posit that the theorizing on High Reliability Organizing has come to a turning point. Our review of literature

(Chapter 2) has learned that the evolution of theorizing on High Reliability Organizations so far is one from the Berkeley school project's focus to the Michigan approach. Our argument that it is time for a new phase is that the two previous phases have replaced one *black box* by another. We have not gained real insight in the why and how high reliability is achieved, neither on what role situational circumstances play in its emergence. We provide the following arguments for this statement:

1. The reliability theme has not sufficiently taken into account the tension between effectiveness and efficiency. Even though it has been discussed by HRT and NAT theorists, it has not been formally integrated into their framework. Since reliability– especially today when pressure to be efficient is high – is one of the competing organizational objectives, any sound theory development cannot happen when the duality effectiveness/efficiency is not genuinely acknowledged as an endogenous factor.
2. The reliability theme has not sufficiently stressed the dynamic nature of organizing. Although it has described reliability as 'a dynamic non-event', it has univocally described its constituting parts in a static way: a culture of mindfulness, a structure of resilience, without pointing out how these contextual and structural dimensions contribute to reliability. Knight (2004, p. 49): "*Thus, while Weick et al.'s (1999) theory proposes that the five processes lead to collective mindfulness, it is plausible that collective mindfulness leads to these five processes. […] Future research is needed to determine the causal relationship between collective mindfulness and the five processes and evaluate Weick et al.'s (1999) conceptualization*".

Just as the Michigan framework has built on the Berkeley research, we argue that we need to take the Michigan research as a starting point. What is needed is a re-appreciation of the Berkeley findings and a rereading of work that has lead the Michigan scholars to their theorizing. With this we mean that one should do a backward reading of Weick's work: from (1) HRO (Weick et al., 1999), over (2) SenseMaking (Weick, 1995) and (3) Loose Coupling (Orton & Weick, 1990), to (4) The Social Psychology of Organizing (Weick, 1979).

In what follows, we start the elaboration of what could become a third phase in the development of High Reliability Organizing, after the pre-1999 Berkeley and the post-1999 Michigan approach. We do so by drawing on the insights and notions described above, by organizing them around five 'building blocsk' which originally come from Roberts and Bea (2001b)[56]: (1) *Flexible Organizational Structuring*; (2) *Attention to Reliability as a Rival to Efficiency*; (3) *Avoiding Core Competencies Becoming Incompetencies*; (4) *Adequate SenseMaking* and (5) *Group Performance and Heedful Interaction*. This calls for a nuanced and encompassing instrument. For this reason, we have explicitly and deliberately chosen for an analysis based on a comprehensive framework.

The factors that – according to literature – constitute the essence of High Reliability Organizations are not systematically grouped, other than around the constructs of Mindfulness and Resilience. This is the same observation as the one made by Knight (2004) in his study on the HRO traits in the management of public swimming pools. Knight found no evidence of Weick et al.'s (1999) conceptualization of five antecedents to be accurate either. Instead, he found indications that the use of three variables would be more appropriate. Therefore, what is needed is a framework that does allow regrouping them in a way that makes sense to the reader and that respects their essence, i.e. without reducing them to mere concepts from organization theory. It is our conviction that the choice for a relevant framework that meets these exigencies is paramount in view of a thorough understanding of the complexity of the fundamental nature of high reliability thinking.

The end of this journey will be a return to the Berkeley starting point, but complemented with insights of some quarter of a century of literature on organizational (un)reliability and insights stemming from our own field experience. In the remainder of this chapter we center this reconceptualization exercise around the variables in our model. On the level of the independent variables, we first discuss the expansion of the HRT framework (Section 3) and Sensemaking (Section 4). On the level of the moderator variables, we address Requisite Variety (Section 4.4), Structure (Section 5) and IS Fit (Section 5). On the level of the dependent variables we describe the way reliability is measured (Section 8).

3 HRT

Our proposed reconceptualization of HRT consists of six constructs: Team Orientation (3.1), Threat Flexibility (3.2), Efficiency (3.3), Sensitivity to Operations (3.4), Preoccupation with Failure (3.5), and Deference to Expertise (3.6). The three first constructs are novel to HRT, the last three have been discussed at length in HRT literature. The focus in this section therefore is on the discussion of the former constructs.

3.1 Team Orientation

Roberts and Bea (2001b, p. 182) state that reliable organizations are characterized by social conduct and collective mental processes that are more fully developed than they are in organizations that are less reliable. People in these organizations create the social forces of groups by acting as if those forces exist. When people believe these forces are present in the group, they construct actions to contribute to the group while envisaging a social system of joint action, representing the system in their minds, and interrelating their actions with the envisaged system. Roberts and Bea argue that people in such organizations act heedfully, i.e. more carefully, critically, consistently, purposefully, attentively, studiously, vigilantly, and conscientiously (Roberts & Bea, 2001b, p. 182). Likewise, Campion et al. (1996, p. 450) suggest to monitor and encourage positive team processes: communication, workload sharing, social support, team self-efficacy or team spirit. Therefore this subsection focuses on the role of team behavior and the interaction that takes place between team members. To this end, we first provide a definition of team and Team Orientation. Next, we elaborate on how mindfulness occurs through interaction between people.

A team is an entity made up of at least two individuals who see themselves and who are seen by others as a social entity because they have been assigned specific roles or tasks to perform, who are interdependent in their work as they work towards a common goal, who are embedded in one or more larger social system(s) (e.g. a business unit or an organization), and who perform tasks that affect others (e.g. colleagues, customers, suppliers) (Bernard, 2006;Rasker, 2002). . Team members have usually been recruited for their qualifications, experience, and skills with the objective of accomplishing a common team goal. Teams have a boundary, which is more or less permeable. Depending on the context, members can move in and out of a team over time

(Bernard, 2006, p. 2). Team Orientation then is the degree to which team members rely on each other for the coordination of their action. Essential in this is the notion 'shared mental model' and the role of implicit coordination. Rasker (2002) describes the shared mental model as organized knowledge structures that allow team members to describe, explain, and predict the teamwork demands. It comprises team knowledge such as knowledge about the tasks, responsibilities, and informational needs of the team members and situation knowledge such as knowledge of the ongoing developments in the external situation. Implicit coordination stands for team members adapting to contingency, e.g. by providing each other the necessary information in advance of requests. Hence, team members anticipate on each other's informational needs. Rasker (2002) provides the example of the blind pass in basketball, where a player passes the ball over his or her shoulder to another player without looking and talking. Groups that perform well are likely to have higher levels of cohesiveness (Riddle, Anderson, & Martin, 2000), and members are likely to feel more involvement and connection with one another (Myers & McPhee, 2006, p. 442).

Most assimilating interaction occurs not at the organizational level but at the level of the team and therefore team communication plays a much larger role than organizational influences (Myers & McPhee, 2006, p. 441). This particularly true for HROs since they are characterized by teams whose members must learn to coordinate their activities, develop trust, and rely on each other in order to perform essential aspects of their jobs. Changes in the group's goals, membership, or context bring unceasingly new demands for learning and mutual adjustment (Myers & McPhee, 2006, p. 441).

3.2 Threat Flexibility

Research has shown that when faced with a threat, organizations, groups, and individuals often react with well-learned behaviors or habitual responses (Staw et al., 1981;D'Aunno & Sutton, 1992). For familiar threats, responding in a rigid, habitual way may be effective at reducing the threat (Staw et al., 1981). However, if the threat is new, habitual responses may be maladaptive and may exacerbate the situation (Plotnick, Turoff, & Van Den Eede, 2009). This response rigidity has been observed under many different kinds of threats, from financial threats to emergencies that threaten to cause loss of life. Threat Rigidity theory is discussed by several authors: D'Aunno and Sutton (1992) on the response of Drug Abuse Treatment Organizations to financial restriction, Gladstein and Reilly (1985) in the context of a threat simulation experiment, D'Aveni and MacMillan (1990) in relation to behavior of CEO's financial crisis behavior.

3.2.1 Threat Rigidity

The threat rigidity thesis proposed by Staw et al. (1981) attempts to explain and model this particular response to threat, to understand the mechanisms that underlie it, and to explore the consequences of this proclivity towards rigid, maladaptive responses in the face of adversity (Plotnick et al., 2009). In this model, environmental change is seen to lead to a threat; the threat then results in a restriction of information and constriction of control in an attempt to focus limited resources on dealing with the threat and to make certain there is centralized decision-making. This in turn leads to rigidity in response (Staw et al., 1981) (Figure 4.2).

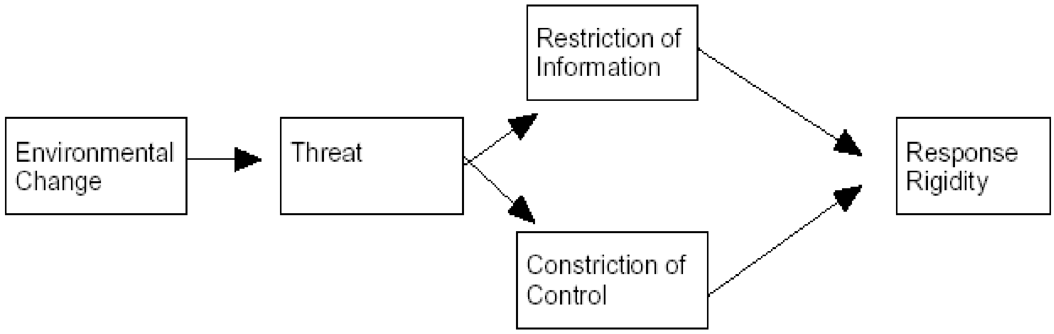

Figure 4.2 - Threat Rigidity (Sutcliffe & Vogus, 2003)

Rather than reducing the stress that precipitates the perception of threat, stress can increase to a point that it is counterproductive. Some stress is needed to focus attention and achieve cognitive absorption. However, there is a point at which too much stress will degrade reliability if the task difficulty and arousal in response to the situational demands are also high (Bea & Moore, 1993). The rigid response, when maladaptive, is ineffective and intensifies the threat. Incremental small environmental changes will produce threats for which learned behavior responses can be effective. But, radical changes will create threats that require new flexible responses. It is this flexible responsiveness that the threat rigidity thesis is lacking (Staw et al., 1981).

3.2.2 Threat Flexibility

Sutcliffe and Vogus' Threat Flexibility model (2003;2007) as shown in Figure 4.3 challenges the Threat Rigidity View

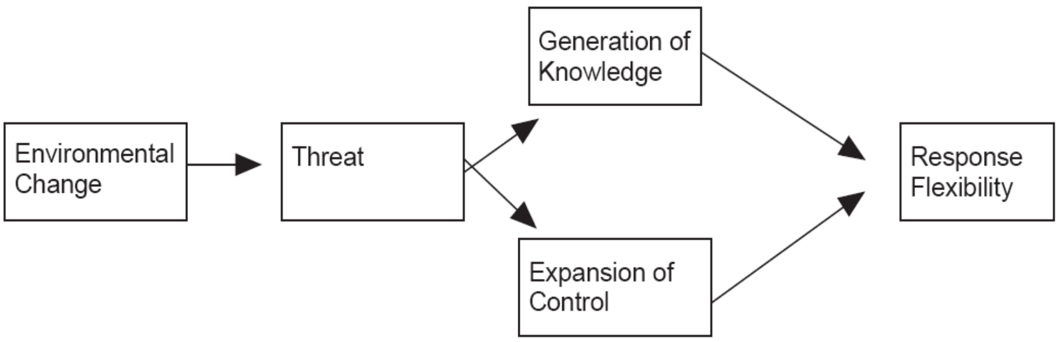

Figure 4.3 - Threat Flexibility (Sutcliffe & Vogus, 2003)

Several researchers have found indications for the existence of the Threat Flexibility model. Smith-Crowe and colleagues (2003), for instance, using training history data and supervisory ratings of 133 hazardous waste workers' safety reliability collected within two organizations in the U.S. nuclear waste industry, examined organizational climate for the transfer of safety training as a moderator of relationships between safety knowledge and safety reliability. Their results supported the proposition that these relationships are stronger in the less restrictive (more supportive) organizational climate (Smith-Crowe, Burke, & Landis, 2003).

HROs are said to be archetypes of resilient response. They achieve this through the plethora of actions and tools that are available to them and that have been discussed throughout Chapters 2 and 4. Yet one particular way of doing so that has not been linked to HRT is suggested by Barnett and Pratt (2000). Their notion of 'autogenic crisis' complements the Threat Rigidity thesis by suggesting that future crises could be pre-adapted by initiating latent threat (instead of real threat) to generate organizational flexibility, learning and renewal. By inducing such autogenic crises into the organization, top-management causes internal fragmentation (Orton & Weick, 1990). The generation of a (be it controllable) crisis induces an uncertainty and ambiguity that has the potential of challenging what has been taken for granted for too long a period of time. In line with Orton and Weick's (1990) reconceptualization of the Loose Coupling metaphor, this boils down to loosening the coupling of (structural and contextual) organizational ties, as such allowing for (tangible and mental) flexibility.

Another hallmark of HROs, is that a lot of what contributes to the leadership style of HROs has to do with the fact that in general managers "*know their problems aren't simple and they know there are many forces at work that can throw their plans out the window*" (Longstaff, 2003, p. 13-14). In non-HROs managers know this also, but there they tend to believe they "*have no choice but to play the game by rules that everybody can at least understand*". If things turn out differently, and damage is caused, a scapegoat is looked for – and found – who will be blamed for the error. HROs ban these practices and this creates a climate of well-being and feeling safe.

3.3 Efficiency

A paradox common to many – if not all – organizations, is the duality between the drive toward efficiency and the drive toward reliability (Roberts & Bea, 2001b, p. 180). Originally stemming from the automobile industry, the efficiency paradigm has penetrated the thinking of managers in both public and private sectors. The business world's obsession with efficiency is a heritage of the Japanese management philosophy of lean thinking. The bottom-line of the lean paradigm is that production time and process time are reduced and that resources are cut: idle time, redundant resources, etc. We treat *'slack'*, *'leanness'*, *'lean thinking'*, and *'efficiency'* as synonyms for which we adhere to Lawson's definition: "*Organizational slack is that cushion of actual or potential resources which allows an organization to adapt successfully to internal pressures for adjustment or to external pressures for change in policy as well as to initiate changes in strategy with respect to the external environment*" (Lawson, 2001, p. 126).

In theory, it does not matter whether slack is constantly available or that it is a potential that can be called upon in time of need. It has the connotation of 'weak', 'loose', 'lazy' or even waste (cf. pit coal), all of which are rather pejorative. This negative connotation has been reinforced by management literature (Harrison, 1997). Even though the blind acceptance of the efficiency model and its alleged suitability, regardless of the context, has been criticized (e.g. Green, 1999), its popularity has hardly diminished. The reason is simply that a striving for efficiency does yield observable benefits. On the other hand, it has become obvious that the fascination for leanness has caused the removal of vital adaptive and responsive capacity or 'organizational slack', necessary for organizations that need to contend with complex and dynamic environments (Smart et al., 2003, p. 733)[57]. "*[E]ngineers are mainly concerned with effectiveness issues; economists with efficiency*" (Jarman, 2001, p. 100). This paradox has been expressed by Roberts and Bea like this: "*One paradox in many organizations is that between the drive toward* *efficiency and the drive toward reliability. By its very nature, efficiency calls for reaching goals in as cost-effective and time-efficient a manner as possible. Most organizations try to do this by downsizing, outsourcing and cutting costs wherever they can. On the other hand, reliability requires constant attention to processes such as intra-group behavior, intergroup behavior, and communications; riveting attention to detail; cross training; paying attention to interdependencies of people, their organizations and outside constituents; and time-consuming vigilance. Efficiency is obtained through rational decision making; reliability is often achieved through trained intuition and in-depth analyses*" (Roberts & Bea, 2001b, p. 180-181).

The challenge is to determine where the critical point of too much leanness lies. This subsection's objective is to shed some light on the determination of this balance between a striving for efficiency and a preoccupation with effectiveness. It builds largely on work by Smart et al. (2003) who argue that "*integrating `lean' thinking with `high-reliability' thinking, presents a significant future challenge for managers reared almost exclusively on a diet of efficiency gain and shareholder value*" (Smart et al., 2003, p. 735-736). In line with this position, we adhere to the general belief that HROs trade off efficiency for reliability because short-term efficiency may significantly undermine long-term viability by causing an organization to make potentially fatal errors of omission (Vogus & Welbourne, 2003a, p. 885). In what follows we address this paradox in more detail. First, we provide an overview of the different slack types (3.3.1), after which a reminder of the classical HRO paradigm that warns against fine-tuning is presented (3.3.2). Finally, a balanced view on this paradigm is developed (3.3.3).

3.3.1 Slack

The slack and redundancy topic has strong relevance for the study of organizational reliability and more particularly to the HRO notion, as high-reliability theorists emphasize redundancy as one of the most prominent design features of unusually successful organizations (Roberts, 1990b;La Porte & Consolini, 1991). Schulman posits that important conclusions can be drawn by "*managers everywhere, especially those concerned about upgrading reliability in the face of diminished reservoirs of organizational slack*" (Schulman, 1993b). He distinguishes between resource slack, control slack (Schulman, 1993b, p. 353-354) and conceptual slack (Schulman, 1993b, p. 364).

Slack types

Resource slack is the surplus in terms of time, personnel, money and so on. It can be viewed negatively as nonproductive inefficiency in the organization, as a suboptimal allocation of resources. Two particular types of resource slack are (1) *Technical redundancy* and (2) *Social redundancy*. Technical redundancy is slack that is embedded in the form of duplication and backups – redundant computer and communications systems, backup power supplies, and multiple safety devices (Ericksen & Dyer, 2005, p. 29). Social redundancy is much less mentioned in HRO literature (Snook, 2002, p. 210). *Control slack* implies individual degrees of freedom in organizational activity, some range of individual action unconstrained by formal structures of coordination or command (Schulman, 1993b, p. 353-354). *Conceptual Slack* (1993b, p. 364) refers to a divergence in organizational member's analytical perspectives about the organization's technology or production processes, a willingness to question what is happening, rather than feign understanding, and greater usage of respectful interaction to accelerate and enrich the exchange of information (Weick & Sutcliffe, 2001, p. 70-71). It is "*a divergence in* *analytical perspectives among members of an organization over theories, models, or causal assumptions pertaining to its technology or production processes*" (Schulman, 1993b, p. 364). Although it can be assessed negatively, as ambiguity or confusion in an organization's knowledge base, conceptual slack forces an organization to take less for granted and to remain vigilant. In this sense, conceptual slack relates to Mindfulness.

Redundancy absorption

The distinction between actual and potential slack is important from the perspective of *efficiency*. The continuous search of striking a balance between an urge to be effective and one to do so with the least resources possible (efficiency) tends to lead to a victory of the proponents of efficiency. Singh (1986) distinguished between unabsorbed slack, which is easy to recover, and absorbed slack which is not easy to recover. If slack is absorbed, it means that slack is interwoven in the organizational tissue, structurally and inextricably. It are resources of any kind that can be recovered to influence reliability over a typical temporal cycle to which managers' activities are entrained. Underlying these aspects of slack typology is the time frame over which resources can be redeployed (Nohria & Gulati, 1996, p. 1246-1247). In a study on reliability in high-velocity environments, one would expect that slack is seen in a short-run time dimension, which comes down to absorbed slack: The decision sequences have to occur in such a limited time-interval that slack simply has to be 'innate' to be effective. Often, there simply is no time to free-up the 'unabsorbed' capacity. An important exception, however, is that if the mechanisms to draw on them are innate themselves, a choice for unabsorbed slack would be a way to combine effectiveness and efficiency. Unabsorbed slack is more efficient than slack that is not: not only can it be cut away with a next budget round – which is a negative interpretation of our statement, but which applies – but also, using a football term, it can play a *sweeper* (or *libero*) position in the organization's defense. The form this unabsorbed capacity can take can vary from a 'flying brigade' (human resources), back-up infrastructure (e.g. computer rooms, offices), unbound experts, etc... Key to the success of unabsorbed slack is to be sure it can be triggered at the right time, in the right way so that it becomes quasi 'on the fly' innate to the organizational components it is reinforcing. Therefore, the advice we could formulate to find a balance between effectiveness and efficiency is to make the slack itself unabsorbed, but the mechanisms that trigger them innate to the organization.

The drawback of slack

A caveat on the side-effect of the slack treatment, however, is that some of the approaches typically used to reduce component failure accidents, such as redundancy, may actually increase the likelihood of system accidents because it increases interactive complexity, which is one of the basic causal factors of unreliability—(Leveson, 2002, p. 32). Apart from this increase of inherent complexity, redundancy can increase the chances of an accident by encouraging operators to push safety limits well beyond where they would have, had such redundancies not been in place (Snook, 2002, p. 210). Snook further reports that redundancy in form of multiple overlapping components "*dramatically increase system complexity, automatically compensate for hidden weaknesses, effectively stymie attempts to locate root causes and generally frustrate learning*" (Snook, 2002, p. 210).

A final observation Snook makes is that the components of redundant systems are quite often much less independent than we think (Snook, 2002, p. 211). While often no more than an irritating design challenge in purely technical systems, meeting the demand for independence in a social system is next to impossible. "*Everyone was responsible, hence no one was*" (Snook, 2002, p. 211).

3.3.2 Classical HRO paradigm on efficiency: the danger of fine-tuning

HROs seem to strike a balance between rewarding efficiency and rewarding reliability. Firms that have reduced numbers of accidents are fully aware of the simple truth that what gets measured gets managed (Roberts & Bea, 2001a, p. 74). They seek to establish reward and incentive systems that balance the costs of potentially unsafe but short-run profitable strategies with the benefits of safe and long-run profitable strategies (Roberts & Bea, 2001a, p. 74). They genuinely acknowledge the complexity they are dealing with in the sense that they believe there are no simple and stable answers. They trade off efficiency for reliability because short-term efficiency may significantly undermine long-term viability by causing an organization to make potentially fatal errors of omission (Vogus & Welbourne, 2003a, p. 885). They focus on the notion of creating an HRO that privileges integrity in the achievement of medium- and long-term goals over short-term efficiency gains.

Although apparently opposed to each other, there is a relationship between both concepts, which is explained below.

1. Long-run reliability will affect *financial reliability*, which in its turn is a precondition for innovation, e.g. Research & Development, leading to innovative products or services.
2. In a world of uncertainty, an organization's *stakeholders* will value reliability. Flexibility (e.g. innovations) is an important signal of reliability and future reliability. In this way, flexibility contributes to reliability.
3. An organization that has committed itself to be highly reliable by applying HRT principles has an organizational model that is built on trust and mindfulness. Such an organization has to explore and maintain more ideas and has to refresh its picture of the environment more frequently (Vogus & Welbourne, 2003a), all preconditions for flexibility. "*The tendency to seek confirmation and avoid disconfirmation is a well-honed, well-practiced human tendency. That is why HROs have to work so hard and so continuously to override this tendency and to remain alert. And that is why you may have to work just as hard. All of us face an ongoing struggle for alertness because we face an ongoing preference for information that confirms*" (Weick & Sutcliffe, 2001, p. 35). Cognitive dissonance kills mindfulness, kills reliability.
4. Long-run flexibility in its turn will make sure the organization is *resilient* in the way it copes with incidents.

Reliability often can only be realized at the expense of short-term efficiency. When shareholders are taking a short-term perspective (profit taking or aiming at dividend increase), this would mean that there is no support for a policy of high reliability. Reliability comes at a cost and, in the short run, such a reliability policy will have a negative impact on share prices. The same scenario occurs, when the organization is operating in a dynamic environment – e.g. urging on innovation – there will be insufficient resources and/or management commitment to focus on the issue of reliability (Vogus & Welbourne, 2003a). HRT has some suggestions on the way this long-term reliability can be achieved.

3.3.3 A balanced view on efficiency

Although prior research on HROs has noted that HROs pursue reliability at the expense of efficiency (Creed et al., 1993) we have found indications that such might not univocally be the case. Therefore, we believe that the trade-off between efficiency and effectiveness is more subtle than that. Schulman (1993a) has typified reliability in HROs a 'non-marginalizable' property, meaning that they confront the economic rule of rationality. Non-HROs, when organizational resources reach the point of diminishing marginal returns, their consumption is likely to be reduced or rationed. (Schulman, 1993a, p. 34). In line with Amalberti et al. (2005) however, we do not agree, and would argue that non-marginalizability would be a characteristic of an ultra-reliable organization (URO), and not of a highly reliable organization. UROs are ruled by the primacy of safety instead of the holistic notion of reliability we have described in the introduction (Chapter 1). Another argument is that where Corporate Governance models propagate the importance of openness and transparency, HRO literature however seems to indicate that openness and reliability is not always compatible. Heimann (2005) argues that for instance for NPPs, there is an obscurity and opaqueness that surrounds the sector of nuclear energy, the so-called Nuclear black box. Nuclear incidents or safety problems at nuclear sites rarely get the news, with a few notable exceptions (e.g. Vartabedian, 2006).

The task for the non-URO – and they constitute the vast majority of all organizations – is to integrate both 'lean thinking' and 'high-reliability' principles (Smart et al., 2003, p. 733). Our own research therefore starts from the bidirectional nature of this relationship between a striving for effectiveness and a continuous concern to be efficient. We do so by taking into account the (1) time horizon, (2) adaptive capacity, (3) system wide perspective, (4) curvilinearity, and (5) risk appetite.

Time horizon

HROs pursue efficiency at the expense of short-term effectiveness, at least at the cost of an increase in its probability. In other words, it is not wrong to strive for efficiency by cutting on costs, time and resources. On the other hand, a strategy of striving for efficiency can be advisable to a certain extent. On the other hand, a remark that also has to be made is the risk of tautology: high performing companies over the years tend to generate slack. In other words, slack is associated to reliability which precisely generated it (Durand, 2004), which constitutes a system dynamics dimension in thinking about slack.

System-wide

HROs embrace lean thinking as a system-wide organizational philosophy, not as an isolated initiative (Smart et al., 2003, p. 735). They focus on their value-streams rather than on their cost-streams. Non-HROs pursue lean thinking in extensive attempts to cut transactional costs, threatening an organization's medium-term sustainability.

Adaptive capacity

The conventional approach to management is reactive and adaptationist (Staber & Sydow, 2002). Organizations following this approach tend to adopt a 'lean and mean' strategy, focusing on their core competencies, streamlining routines, and tightening resource belts (Harrison, 1997). They view organizational flexibility in terms of cost cutting, rationalizing, and routinizing and "*behave as if complex, dynamic and interrelated environments are in fact simple, static and* *unrelated*" (Bozeman & Slusher, 1979, p. 346). The adaptationist approach considers organizational slack a form of inefficiency and frowns on experimentation with unproven structures and procedures, if such experimentation is seen as conflicting with activities that have clear and immediate payoffs. An alternative strategy is to develop adaptive capacity (Staber & Sydow, 2002, p. 408). HROs are archetypes organizations that go for adaptive capacity instead of adaption. The distinction between adaption and adaptive capacity is crucial in explaining HRO success and has the potential of distinguishing between the real HRO and the organization that is highly reliable by chance or because it is an Ultra Reliable Organization (URO).

Curvilinearity

Durand (2004) argues that too much slack, like too much organizational knowledge, is bad though. Too much knowledge can be a hindrance in developing responses to complexity. The organization will develop negative organizational slack, which will lead to some form of inertia and rigidities. Nohria and Gulati (1996), for instance, report a similar effect of slack on innovation. They point out the curvilinear nature of the relationship by arguing that too little slack inhibits innovation because it discourages any kind of experimentation whose success is uncertain, but that at the same time complacency and lack of discipline might occur as the consequence of too much slack (Nohria & Gulati, 1996, p. 1245) [58]. An inverse U-shaped relationship like this, suggests that, taken together, an intermediate level of slack is optimal for innovation. We hypothesize that the same mechanisms that apply to the relationship between innovation and slack equally can be found in the relationship between slack and other aspects of flexibility (innovation being one of them) and reliability.

Therefore, you have positive or 'good' organizational slack and you have negative or 'bad' organizational slack. The question remains however, what makes the difference between these two. We have the feeling that HROs seem to have found a recipe for developing the positive variant.

Risk appetite

In her review of Sagan's 'The Limits of Safety' (1993), Rousseau (1996) comments on the nature of the debate between HRT and NAT: "*Since each acknowledges the catastrophic potential for failure, what they disagree on is whether the risks are worth it. Such a question is not amenable to scientific test*" (Rousseau, 1996, p. 201). This observation can be depicted by a Taylor-Russell diagram where the trade-off between Type I and Type II errors is described (Heimann, 2005).

Type I and Type II errors can be described as follows [59]:

- A Type I error (Neyman and Pearson, 1933/1967), also known as an error of the first kind, occurs whenever the solution turns out to be inadequate, given the problem has been correctly identified and analyzed. Such an error relates to rejecting a null hypothesis when it is actually true.
- A Type II error (Neyman and Pearson, 1933/1967), also known as an error of the second kind, occurs whenever the solution turns out to be inadequate because of a wrong analysis given the problem possibly has been incorrectly identified. It is the error of not rejecting a null hypothesis when the alternative hypothesis is the true state of nature.

The following is an example: "*Moreover, the actors seemed to take into account the cost of making a mistake through action (shooting down an unarmed plane) along with the cost of* *making a mistake through inaction (not shooting down an armed plane)*" (Heimann, 2005, p. 8). Typical of HRT research is that the organizations it studies have to cope with 'hazardous yet high-reliability technical systems' and that in such systems failure is not an option because that would/could potentially radically jeopardize its survival. Schulman continues that in such organizations reliability is not considered a probabilistic property '*that can be traded off at the margins with other organizational values*', but has to be considered a dichotomous organizational variable (Schulman, 2001, p. 346).

From a reliability standpoint, an organizational structure that is effective for preventing one type of error may not be equally effective at preventing the other (Little, 2005, p. 2). The message that can be derived from the diagram is that an implicit choice for efficiency (avoiding a Type I error) unavoidably leads to an increase in the risk of a Type II error. Van der Pijl and de Wild (2007, p. 10) call this degree/amount of risk an organization is willing to accept in pursuit of value *risk appetite*. As the acceptance of risk is conditional on the pursuit of value, it is clear that risk cannot be seen in isolation. The balance inherent to the Taylor-Russell diagram (Figure 4.4) shows this, but at the same time it is our assertion that HROs are capable striking a balance that minimizes Type I errors (catastrophic failure) while at the same time keeps Type II errors (excessive and costly conservatism) at acceptable levels (Little, 2005, p. 5).

		State of Nature	
		H_0	H_1
Decision	H_1	a Type I error incident with severe loss	Correct Decision
	H_0	Correct decision	ß Type II error Missed opportunity Wasted resources

(a) Minimizing alpha

		State of Nature	
		H_0	H_1
Decision	H_1	a Type I error incident with severe loss	Correct Decision
	H_0	Correct decision	ß Type II error Missed opportunity Wasted resources

(b) Minimizing beta

Figure 4.4 - Taylor-Russell diagram

A crucial factor in the determination of the risk appetite is what Heimann (2005, p. 115-116) calls 'the bottom-line question about reliability', namely whether risky technologies can be managed so as to achieve error-free operations for extended periods of time when the commitment by political and organizational leaders is missing. He posits that HRO principles of redundancy, culture, and learning will have no or much less effect when the steadfast motivation to pursue a course of action is missing. Although this bottom-line question is quintessential in HRO thinking, it might be taken for granted too easily. When asked about commitment in general terms, and independent from the specificity of a situation, people (and especially management) are inclined to answer truthfully affirmatively.

3.4 Sensitivity to Operations

The Sensitivity to Operations constuct has been elaborated at length in our review of literature (Chapter 2). We refer the reader in this respect to Chapter 2, subsection 3.2.2.

3.5 Preoccupation with Failure

The Preoccupation constuct has been elaborated at length in our review of literature (Chapter 2). We refer the reader in this respect to Chapter 2, subsection 3.2.2.

3.6 Deference to Expertise

Like the two previous constructs, Deference to Expertise stems from insights in High Reliability Organizing gained by the Michigan School (Weick et al., 1999).

The Deference to Expertise construct bridges the divide between HRO literature and common organization theory. Mendelson (2000, p. 517), for instance, posits that information age decision architecture is embedded in the research of both organizational theorists (Lawrence & Lorsch, 1967;Thompson, 1967;Galbraith, 1973) and economists (Hayek, 1945) as they show that moving decision rights closer to the point of information reduces information-processing requirements. In HRO jargon, this is called '*Deference to Expertise*'.

The Deference to Expertise construct is also at the heart of explaining high reliability. In this section we address mainly the dilemma of the need of simultaneous centralization and decentralization that is at the core of NAT (See: Chapter 2 – Literature Review). It connects to the Roberts and Bea Building Block of 'Flexible Organizational Structuring' (Roberts & Bea, 2001b). We recall that, from a NAT perspective, tightly coupled and interactively complex systems are doomed to fail because of their impossibility to be centralized and decentralized at the same time. HRO researchers – Weick (1987) and Rochlin (1989) – propose a solution to this dilemma, namely the HRO capability to maintain both. HRO research explains this phenomenon as "*a successful management of the two opposites: central planning on the one hand providing coordination between individuals, and local improvisation of individuals' actions on the other hand. Yet for the people involved the situation was not one of carefully balancing the two opposites, but rather one of going through a quite unproblematic process of 'planning' and 'performing'*" (Gauthereau & Hollnagel, 2005, p. 128). In essence, this dilemma can be solved by integrating the design principles of stability and flexibility, rather than merely substitute the one for the other (Smart et al., 2003, p. 734). In this lies the challenge HROs are facing on a daily basis. Noteworthy is Gauthereau's and Hollnagel's (2005) argument that this is quite a natural process as people in HROs usually do not concern themselves with this centralization-decentralization conflict (Rochlin, 1999). In part, this observation equally counters the critique from NAT that HROs are cognitively impossible.

In the remainder of this section, we deal with the essence of *Deference to Expertise* and its preconditions: Trust (3.6.1), (Control slack (3.6.2), Hierarchy vs. bureaucracy (3.6.3), DecisionMaking styles (3.6.4), Training (3.6.5), Boundary spanners (3.6.6), and Layered architecture (3.6.7).

3.6.1 Trust

Schulman has described trust as the '*lubricant of the organization*' (Schulman, 1993a, p. 46). Because of its perishable nature, it has to be continually nurtured and renewed if it is to survive. Trust never gets institutionalized. It is one party's willingness to be vulnerable to another party based on the belief that the latter party is competent, open, concerned, and reliable (Mishra, 1996). In that sense, trust must be distinguished from related behaviors such as cooperation or delegation. These behaviors follow from one's trust in another (Mishra, 1996). Therefore, when HROs defer to expertise, it is because they meet the trust precondition.

Despite its importance, research on HROs has shown little attention for the role of trust as a prerequisite for high reliability. One notable exception is the work of Cox et al. (2006) who have studied – for two types of high reliability settings, the nuclear and offshore industries – the importance of high trust relations and their associated impact on safety culture. However, this study has not gone into the HRO mechanisms themselves, but has merely referred to HROs as a type of safety-critical organizations "*that have not just avoided failure through good fortune or the vagaries of probability, but that have actively managed to control and reduce the risks of technical operations whose inherent hazards make them prone to catastrophic failure*"(Cox, Jones, & Collinson, 2006, p. 1125). Although the Cox et al. study describes trust as a precondition for high reliability in terms of safety, it does not address the link between the trust construct and the Berkeley or Michigan HRO constructs. This observation can be made for HRO research in general, as it deals with the trust construct only distantly (e.g. Myers & McPhee, 2006;Baker, Day, & Salas, 2006). More frequent are HRO studies that take an implicit approach to the trust theme.

3.6.2 Control slack

Control slack implies individual degrees of freedom in organizational activity, some range of individual action unconstrained by formal structures of coordination or command (Schulman, 1993b, p. 353-354). Weick (1995) suggests that organizations operate with three forms of control: "*First-order control by direct supervision, second-order control by programs and routines, and third-order control consisting of assumptions and definitions that are taken as given. Third-order controls are called 'premise controls' because they influence the premises people use when they diagnose situations and make decisions. Premise controls were the 'professional blind spots' […] They are the deep assumptions that are the foundations of culture [..]*" (Weick, 1995, p. 113-114). Together these control types, determine an organization member's degree of self-efficacy, which is a prerequisite for a successful Deference to Expertise.

3.6.3 Hierarchy vs. bureaucracy

A mistake easily made when studying organizations and the reasons for their success or failure is to confuse hierarchy with bureaucracy. This distinction is pointed out by Hirschhorn (1993). He argues that "*working in hierarchies, people can respond flexibly to their task demands. But when organizational leaders cannot or will not manage the inherent risks of the enterprise they paradoxically undermine the hierarchy and create a dysfunctional bureaucracy in its place. Diffusing responsibility and reducing the leader's apparent accountability, the bureaucracy burdens employees while making it difficult for them to work. Bureaucracies, in effect, deform the hierarchical structure. We need to construct hierarchies in which authority is widely delegated, while the chain of command is preserved and secured*" (Hirschhorn, 1993, p. 138). This distinction between hierarchy and bureaucracy helps to explain the *Deference to Expertise* property. By blending a hierarchical decision structure with a specialist decision structure, HROs recognize – and operationalize – a principle that often escapes decision makers at critical moments: Expertise and experience are usually more important than rank (Weick & Sutcliffe, 2001, p. 74). Ruchlin et al. (2004), in their review of literature on leadership and safety rely both on HRT and NAT. They reach a similar conclusion: "*However, there is also recognition of the* *importance of human agency in shaping directions and being innovative. Furthermore, an important role of organizations becomes to experiment, learn and adapt. This leads to the emergence of strategy. But contrary to the top-down design approach, this autonomous strategy is less anchored in strong leadership but rather grows from bottom-up actions and middle management engagement. This view challenges the previous role understanding of top management. Competences take time to evolve, knowledge cannot be designed*" (IBM Business Consulting Services, 2004, p. 31).

3.6.4 Decision-making styles

Typical of HROs is that they know many diverse decision-making styles, all based on the principle that it is natural to change from a bureaucratic style to a collegial style in situations where this is more convenient (Grabowski & Roberts, 1997). The precondition is the existence of 'slack' and 'safe areas': decision makers can consider, off-line, the potential impact of their decisions (Grabowski & Roberts, 1997, p. 9).

Another characteristic is that HROs are reluctant to simplify (Weick & Sutcliffe, 2001, p. 11-12). Traditional management approaches favor working with simplifications (e.g. Key Reliability Indicators, KPIs), meaning a reduction of complexity through aggregated indicators. This is in contrast to HRO's continually redefining of their organizational structures, their decision-making styles, and their communication patterns in response to the needs of their environment

Just as HROs know different decision-making styles, they also feature multiple authority structures. Grabowski and Roberts (1997) distinguish between 'Rapid tempo for the build-up stage', 'Structural reporting for the maturation stage' and 'Bureaucracy for the maintenance and resolution phase'. In emergencies, in order to avoid the inconveniences and even dangers of rigid hierarchies "*[…] HROs push decision making down—and around. Decisions are made on the front line, and authority migrates to the people with the most expertise, regardless of their rank*" (Weick & Sutcliffe, 2001, p. 16). A different approach for each different situation is a good principle on the condition that it can be implemented in the organization in a natural/automatic way. This is subject to the premise of simultaneous tight and loose-coupling, for which flexibility and redundancy (slack) are the necessary constituents (Grabowski & Roberts, 1997).

In general, HRO decision making is carried out in settings where (Grabowski & Roberts, 1997, p. 156-157):

- organization members are in close physical proximity to each other.
- there is consistency among beliefs, actions and decisions
- there is avoidance of public, irrevocable, escalating decisions
- there are limitations of leadership uncertainties
- there are collegial authority and decision making patterns which overlay bureaucratic patterns

3.6.5 Training

A remedy for the non-linearity of the number of states is found in constant training with the aim of presenting possible scenarios organization members could face (Roberts, 1990a). An emphasis on training has two advantages, both leading to the same result of increased reliability. The first benefit obviously is that routines are exercised. It has been reported on several occasions (e.g.

Tarn et al. (1998)) that lack of training is a reason why even small incidents activate a domino effect and lead to disaster. The better people are trained, the bigger is their frame of reference. This frame of reference serves as stepping stones to find a solution for crucial situations. We call this 'Training as a Product'. From the perspective of 'Training as a Process', we argue that the mere fact of providing training to organization members on itself is a signal for them to remain aware of the brittleness of reliability. This comes down to training as an antidote for organizational hubris, the overconfidence which is the harbinger of calamity (Matthews, 2004).

Like all effective forms of learning – and according to a social-constructivist vision on learning – training should be based on active participation, action learning or other participatory forms of training, e.g. in communities of practice (Aase & Nybø, 2002).

3.6.6 Boundary spanners

We stress the importance of 'boundary spanners' (Boland & Yoo, 2003) in connecting people and processes, as such making rich and varied information available to decision makers throughout the organization. They are *bridge builders* because of their inter-functional and inter-disciplinary background. These boundary spanners should have "*diverse experience, skepticism toward received wisdom, and negotiating tactics that reconcile differences of opinion without destroying the nuances that diverse people detect*"(Weick & Sutcliffe, 2001, p. 11-12). Boundary spanners think end-to-end and as such, they not only help the organization in its attempt of becoming more reliable, but also in becoming more flexible and customer-oriented.

3.6.7 Layered architecture

HROs have been described as having a layered organizational structure (Lawson, 2001, p. 127). By this, Lawson means that HROs can operate according to at least three very different models on an as-needed basis: (1) hierarchical, (2) completely collegial and team-based and (3) acting as a disciplined machine during emergencies. The presence of such layers represents a challenge for communication. Yet, HROs foster varied communication. Effective and varied communication is one of the hallmarks of HROs, which provide a means of understanding roles, responsibilities, and relationships and is as such developing shared mental models among members of the organization (Grabowski & Roberts, 1997, p. 156). As a result, autonomy and interdependence between system members is made explicit and more understandable, thus providing opportunities for SenseMaking and discussion of improvements in the system (Grabowski & Roberts, 1997). This can be obtained by means of frequent briefings, multiple instances and opportunities for shared information (discussions), and acknowledgement of the necessity of talk at the individual, team, organizational and system level. The explicitation of an individual's uncertainty through communication is also essential as uncertainty increases risk (Grabowski & Roberts, 1997). In this perspective, Aase and Nybø (2002) advocate so-called 'spaces of non-punishability' where failures and near failures could be analyzed and discussed.

4 SenseMaking

From Chapter 2, Section 5, we have learned that it is not easy to define SenseMaking. Weick (1995;2005), for instance, refuses to describe SenseMaking as an exhaustive, limitative and exclusive enumeration of properties. Instead he clarifies that the seven properties (See Chapter 2, Section 5) "[…] *serve as a rough guideline for inquiry into SenseMaking in the sense that they suggest what SenseMaking is, how it works, and where it can fail…This listing is more like an* *observer's manual or a set of raw materials for disciplined imagination than it is a tacit set of propositions to be refined and tested. The listing might eventually serve the latter purpose*". We have taken Weick's advice at heart and have taken these properties as the starting point, but we have reorganized them into a new categorization of SenseMaking components and processes as (1) Self, (2) Other and (3) Scheme (Figure 4.5).

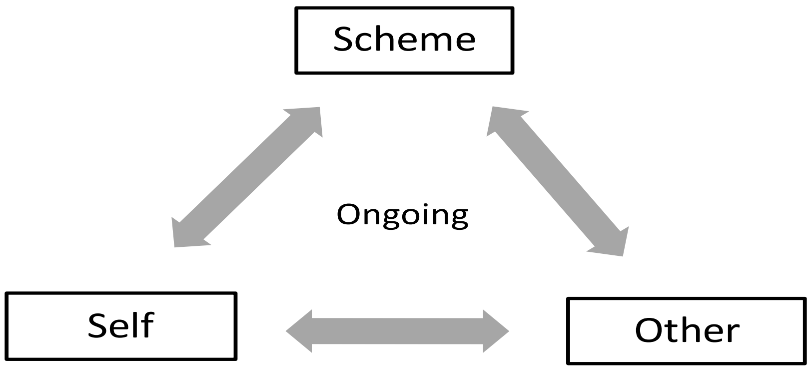

Figure 4.5 - Self, Scheme and Other

Although the seven original properties might not be fully exhaustive or exclusive in the scientific sense, they still are a grand attempt to render the way people deal with interruptions more tangible. Therefore, they continue to act as constructs that underlie our research. For their elaboration, we refer to the Chapter 2, Section 5. From the first section of this chapter and Appendix C we recall that our a priori belief was that the factors would relate to the seven SenseMaking properties, the exploratory factor analysis has shown that the items regrouped along three new constructs, which were labeled:

1. Making sense through team: The role of 'Other' for SenseMaking
2. Making sense through identity: The role of 'Self' for SenseMaking
3. Making sense through heuristics, rules, etc.: The role of 'Scheme' for SenseMaking

The original SenseMaking properties have been attributed to one of these three newly labeled constructs (Table 4.1).

Self	*Scheme*	*Other*
Identity Constructing	Retrospective Enacting Cue Extracting Plausibility	Social

Table 4.1 - Self, Scheme and Other

This attribution makes – at least to us and for our purposes – more sense than the original constructs. Because of their higher degree of mutual exclusiveness, these constructs can be applied more easily. Moreover, we posit that they form a more exhaustive set than the underlying SenseMaking properties because it acknowledges the non-limitativeness of the list.

4.1 Self

Identity Constructing

Depending on who the SenseMaker is, the definition of what is happening will also change. What the situation means is defined by who one becomes while dealing with it or what and who one represents. "*The Sensemaker is himself or herself an ongoing puzzle undergoing continual redefinition, coincident with presenting some self to others and trying to decide which self is appropriate*" (Weick, 1995, p. 20). The organization seeks to discover what it *thinks* and *knows* about itself and its environment. This identity construction is the basis for imparting meaning to information inside an organization, and, eventually, determining what problems must be solved.

Identity can be seen on the level of the individual or on the level of an aggregation of individuals (a team, an organization, a society, a people). Organizational identity, like individual identity for that matter, is not stable over time. It is liable to intense emotional reactions that can redefine organizational identity drastically (Weick, 1995, p. 94). Organizational identity can be described as "*an organization's members' collective understanding of the features presumed to be central and relatively permanent, and that distinguish the organization from other organizations*"[60] (Gioia, Schultz, & Corley, 2000, p. 64).

Identity construction is seen by many to be one of the two basic properties that differentiate SenseMaking from basic cognitive psychology.[61] We create our reality by making decisions based on what we observe and what we are. From the perspective of SenseMaking, who we think we are (identity) as organizational actors lies primarily in the hands of others: "*How can I know who we are becoming until I see what they say and do with our actions?*" (Weick et al., 2005, p. 416). In that respect, this image of self is not static: "*Even if we delve to the 'deep' level of organizational identity, we discover that, contrary to lay conceptions of identity as that which is fundamentally stable and enduring over time, organizational identity is actually fluid and susceptible to prevailing interpretive currents. Identity amounts to a present way of understanding 'who we are as an organization', and although identity might have continuity with past conceptions, it is not bound by them. Only via retrospective interpretation can organization members articulate their identity*" (Gioia, Corley, & Fabbri, 2002, p. 623).

4.2 Other

Social

"*People learn about events when they compare what they see with what someone else sees and then negotiate some mutually acceptable version of what really happened*" (Weick, 1985). Cognitive and social aspects of SenseMaking are inextricably linked. Other people are integral to our efforts to make sense of things because what we say or think or do is contingent on what others say and think and do. Even if we are alone, we imagine the response of others to our actions or thoughts, and adjust our thinking and behavior accordingly. SenseMaking requires talking, interaction, conversation, argument, and dialogue with others. Links or bonds are created through social interaction.

Whenever this section addresses SenseMaking, it does so on the level of the individual. In that respect SenseMaking corresponds to the '*largely cognitive activity of constructing a hypothetical* *mental model of the current situation and how it might evolve over time, what threats and opportunities for each action are likely to emerge from this evolution, what potential actions can be taken in response, what the projected outcomes of those responses are, and what values drive the choice of future action*'. Brenda Dervin is the protagonist of individual SenseMaking. The SenseMaking construct can also be applied on the level of the organization, but then it relates to '*a collaborative process of creating shared awareness and understanding out of different individuals' perspectives and varied interests'*. In that way, collective SenseMaking is what has been described above as mindfulness. When Weick addresses SenseMaking, he addresses it at the organizational level. "*Organization is an attempt to order the intrinsic flux of human action, to channel it towards certain ends, to give it a particular shape, through generalizing and institutionalizing particular meanings and rules*" (Tsoukas and Chia 2002, p. 570). "*We need to grasp each to understand the other. The operative image of organization is one in which organization emerges through SenseMaking, not one in which organization precedes SenseMaking or one in which SenseMaking is produced by organization*" (Weick et al., 2005, p. 410).

4.3 Scheme

A cognitive scheme is a mental structure people rely on to organize information they come across, based on previous experiences and suitable for present and future SenseMaking (Ericson, 2001, p. 117;Graesser, Gordon, & Sawyer, 1979). It represents one's understanding of the world by filling in white spots where information is missing (Gioia & Poole, 1984). The collection of cognitive schemes of people in a team or an organization is what is called its 'cognitive profile' (Ericson, 2001, p. 118).

Several schemes are available. We categorize them as (1) DecisionMaking and (2) SenseMaking. The following quote makes clear what difference exists between both scheme-building strategies: "*The Westerner and the Japanese man mean something different when they talk of 'making a decision'. In the West, all the emphasis is on the answer to the question. Indeed, our books on decision making try to develop systematic approaches to giving an answer. To the Japanese, however, the important element in decision making is defining the question. The important and crucial steps are to decide whether there is a need for a decision and what the decision is about. And it is in that step that the Japanese aim at attaining consensus. Indeed, it is in this step that, to the Japanese, is the essence of decision. The answer to the question (what the West considers the decision) follows from its definition. During the process that precedes the decision, no mention is made of what the answer might be. … Thus the whole process focused on finding out what the decision is really about, not what the decision should be*" (Weick, 1995, p. 15 (after Drucker 1974, pp. 466-467)). Decision analysis is the scheme fitting a rationalistic and predictable worldview. Interruptions of normal processes can be dealt with by applying the appropriate procedures, well thought-out and well tested. SenseMaking, on the other hand, is the scheme fitting a more complex and less-predictable worldview. Interruptions then call for a more intuitive and novel approach like improvisation to cope with the unexpected.

Retrospective

"*SenseMaking is an examination of past practices in order to learn (and unlearn) things about the current context*" (Nathan, 2004). Weick, Sutcliffe and Obstfeld (2005, p. 413) point out that answers to the question "*What's the story?*" emerge from retrospect, connections with past experience, and dialogue among people who act on behalf of larger social units. Answers to the question 'now what?' emerge from presumptions about the future, articulation concurrent with action, and projects that become increasingly clear as they unfold.

Weick et al. (2005) synthesize it as follows: "*To focus on SenseMaking is to portray organizing as the experience of being thrown into an ongoing, unknowable, unpredictable streaming of experience in search of answers to the question, "what's the story?" Plausible stories animate and gain their validity from subsequent activity. The language of SenseMaking captures the realities of agency, flow, equivocality, transience, reaccomplishment, unfolding, and emergence, realities that are often obscured by the language of variables, nouns, quantities, and structures. Students of SenseMaking understand that the order in organizational life comes just as much from the subtle, the small, the relational, the oral, the particular, and the momentary as it does from the conspicuous, the large, the substantive, the written, the general, and the sustained. To work with the idea of SenseMaking is to appreciate that smallness does not equate with insignificance. Small structures and short moments can have large consequences*" (Weick et al., 2005, p. 410).

Many a theory exists about strategy. Without any doubt, strategy (formulation, implementation, etc.) has been one of the most popular themes for scholars in management. In the majority of these writings and research, strategy is seen as a plan. Mintzberg calls this 'intended strategy', a set of a priori guidelines for future actions). He confronts this intended strategy with what he calls an 'emergent strategy', a strategy that emerges despite a lack of planning. The a posteriori result of intended and emergent strategy is the realized strategy (Houthoofd, 2001, p. 27-28). Because of the complexity of the organizational context, intended consequences might not come true whereas unintended consequences resulting from strategy might be much stronger than imaginable. Mintzberg (1978) has described emergent strategy as a stream of decisions (or even merely of issues) decoupled from action. "[…] *the strategy-maker perceived an unintended pattern in a stream of decisions and made that pattern the intended one for the future. An emergent strategy, once recognized, became a deliberate strategy*" (Mintzberg, 1978, p. 946). Clearly, this is a case of the application of the retrospection SenseMaking property (Schneider, 1997, p. 95).

"*We are conscious of what we have done, never of doing it. We are always conscious directly only of sensory processes, never of motor processes; hence we are conscious of motor processes only through sensory processes which are their resultants […] Actions are known only after they have been completed, which means we are always a little behind or our actions are always a bit ahead of us. To anticipate a later point, if hindsight is a bias […], then everyone is biased all the time. The nature of time and sensing guarantee that outcome*" (Weick, 1995, p. 26).

Cue Extracting

SenseMaking is focused on and by extracted cues. We notice some things and not others. We pay attention and extract a particular cue, then link it with some other idea that clarifies the meaning of the cue, which then alters the more general idea to which we linked the cue, and on and on. The cues we extract from situations tend to be simple and familiar and are crucial for their ability to get us moving. While moving, we keep noticing other areas and we stop to update our understanding as we go along. These extracted cues enable us to act, which increases our confidence and confirms our faith in earlier cues. In essence, we decide what to pay attention to (Nathan, 2004).

Weick (Weick, 1995, p. 50) describes cues as simple, familiar structures that are seeds from which develop a larger sense of what may be occurring. Cue extracting is different from noticing. Starbuck an Milliken (1988, p. 60) refer to noticing as the activities of filtering, classifying, and comparing, and distinguish it from SenseMaking which refers more to interpretation and the activity of determining what the noticed cues mean.

Plausibility

Together with Identity construction, plausibility is seen by many as a pillar of SenseMaking that make it fundamentally different from basic cognitive psychology (Weick et al., 2005, p. 416). [62]

Looking for what is plausible is often of more practical help then finding accuracy (Nathan, 2004). Totally accurate perception is not needed, which is good because what is needed is that which is plausible and reasonable. Plausibility helps us explore what we see and energizes us to act. The search for accuracy on the other hand, can de-energize us as the search drags on and on.

Enactment

Enactment – sometimes called recursion – starts from the belief that the context is not an unchanging environment. It states that organisms (systems, organizations …) are "*like rivers carving their way across a landscape and changing its geography, then being guided by the new topography*" (Boisot & Cohen, 2000, p. 119). "*People often don't know what the 'appropriate action' is until they take some action, guided by preconceptions, and see what happens. Action determines the situation: The product of action is an orderly, material, social construction that is subject to multiple interpretations*" (Weick, 1988). The starting point is that there is no objective environment out there separate from one's interpretation of it. Thus, the organization creates or enacts parts of its environment through selective attention and interpretation. Interpretation can shape the environment more than the environment shapes the interpretation. We act and actions become part of the environment that then constrains future actions. The subsequent action tends to confirm preconceptions. "*[…] people receive stimuli as a result of their own activity, which is suggested by the word enactment. […] we are neither the master nor the slave of our environment. We cannot command and the environment obey, but also we cannot, if we would speak with greatest accuracy, say that the organism adjusts itself to environment, because it is only part of a larger truth*" (Weick, 1995, p. 32). Weick further distinguishes between SenseMaking and interpretation. He posits that SenseMaking is about invention, whereas interpretation is about discovery. "*The act of interpreting implies that something is there, a text in the world, waiting to be discovered or approximated. SenseMaking, however, is less about discovery than it is about invention. To engage in SenseMaking is to construct, filter, frame, create facticity (Turner, 1987), and render the subjective into something more tangible*" (Weick, 1995, p. 13-14).

Several authors (Heimann, 2005;Choo, 2001;Jennings & Greenwood, 2003) have built on Weick (1979) and his Enactment-Selection-Retention (ESR) model of SenseMaking. This ESR model treats SenseMaking as reciprocal exchanges between actors (Enactment) and their environments (Ecological Change) that are made meaningful (Selection) and preserved (Retention) (Weick et al., 2005). "*SenseMaking is an active two-way process of fitting data into a frame (mental model) and fitting a frame around the data. Neither data nor frame comes first; data evoke frames and frames select and connect data. When there is no adequate fit, the data may be reconsidered or an existing frame may be revised*" (Klein, Phillips, Rall, & Peluso, 2003).

4.4 Ongoing

SenseMaking has neither a beginning nor a formal end. Instead, it "*takes place in a continuing and dynamic fashion as events unfold and we continually seek to understand what events mean in relationship to our organizations*" (Nathan, 2004). Most of us at any given time find ourselves 'in the middle of something'. As we move from one situation to another, we make and revise assumptions and beliefs along the way. Our SenseMaking is ongoing. We work at making sense of past events to develop a story that we understand, and as future events unfold, we revise our story. SenseMaking takes place in a continuing and dynamic fashion as events unfold and we continually seek to understand what events mean in relationship to our story. "*SenseMaking never starts. The reason it never starts is that pure duration never stops. People are always in the middle of things, which become things only when those same people focus on the past from some point beyond it. […] To understand SenseMaking is to be sensitive to the ways in which people chop moments out of continuous flows and extract cues from those moments. There is widespread recognition that people are always in the middle of things. What is less developed are the implications of that insight for SenseMaking*" (Weick, 1995, p. 43).

5 IS Fit

The IS Fit theme has already been addressed in Chapter 2 where we looked in general into the issue of aligning Information Systems, users and tasks. Here, we shift the focus further to the way IS could/should support the Incident Management process. More particularly, we do so by studying the way IS are used for the incident registration (5.1) and communication (5.2) and how this relates to the HRT and SenseMaking constructs.

5.1 Registration

Little has been written on IS and Mindfulness, except for a recent publication by Butler and Gray (Butler & Gray, 2006). These authors argue that there are two strategies for achieving high reliability, i.e. routine-based reliability and mindfulness-based reliability and that IS research has typically focused on one of these strategies at a time, not at their individual and cumulative benefits in achieving reliability.

5.1.1 Routine-based reliability

"*Routine-based approaches to reliability are fundamentally Taylorist. Procedures and processes are designed in advance, usually by managers or analysts, and applied in the moment by operators. Information systems are created and training programs are prepared to lead users step-by-step through the proper routine. Procedures, routines, training, and systems are designed to decrease the need for creative human involvement in the moment, in an effort to reduce errors, unwanted variation, and waste*"(Butler & Gray, 2006, p. 214). "*Routine-based reliability implicitly assumes that systems and routines are themselves rationally constructed, stable, repeatable, and reliable. If this is untrue, as suggested by recent studies of organizational* *rules, processes, and systems rather than solving the reliability problem, routines may aggravate it by adding greater complexity and more unreliable components*" (Butler & Gray, 2006, p. 214).

5.1.2 Mindfulness-based reliability

While routine-based approaches focus on reducing or eliminating situated human cognition as the cause of errors, mindfulness-based approaches focus on promoting highly situated human cognition as the solution to individual and organizational reliability problems (Weick & Sutcliffe, 2001). A mindful response 'to a particular situation is not an attempt to make the best choice from among available options but to create options' (Langer 1997, p. 114). Mindfulness-based approaches hold that an individual's and organization's ability to achieve reliable reliability in changing environments depends on how they think: how they gather information, how they perceive the world around them, and whether they are able to change their perspective to reflect the situation at hand (Langer 1989). From this perspective, routines are a double-edged sword. They are helpful when they provide options, but detrimental when they hinder detection of changes in the task or environment. "*Whether describing individuals or organizations, mindfulness-based approaches posit that—more than just consistency of action—properly situated cognition is ultimately the basis for reliable reliability*" (Butler & Gray, 2006, p. 214).

5.2 Communication

5.2.1 IS and SenseMaking

SenseMaking is important enough a process to deserve more attention than it usually gets. Especially in the field of IS, its design and use, the way SenseMaking is supported is decisive for success or failure. Computerized information systems force people to give up the powerful tools that they use to make sense of the world away from terminals. If people are to retain meaning in computer-mediated contexts, managers need to restore the techniques for SenseMaking that machines exclude (Weick, 1985). Weick and Meader (1993) put it like this: "*We assume that people who are confused by equivocal events gain more understanding of these events as they use more SenseMaking activities. Interaction helps alleviate confusion, but more so when action is taken, multiple sources of data are compared, the results are pondered, and the confusion event is placed in a context. It is the contemporary nature of these five activities that seems most threatened when confused people are expected to define and resolve their confusion in front of computer screens. The magnitude of this task is artificially reduced when the task is described as one of problem identification rather than SenseMaking. It is our intention to convey an appreciation of this larger, messier process of SenseMaking, so that designers are made more comfortable when they constrain and exercise some of its features*".

Therefore, in this section, we study those SenseMaking aspects that bear promises for IS design. We continue by discussing current IS design building blocks and their hindrance of SenseMaking activities. We conclude this section by making a plea for a more *open* IS type with the SenseMaking theorem as an underpinning.

5.2.1.1 Relevance

The study of SenseMaking in connection to Information Systems is not new. Apart from the obvious link with information, several researchers have linked SenseMaking theory more particularly to the design of Information Systems. Weick (1985) laid a basis for later work on thinking about SenseMaking in connection to computerized IS by developing a framework capturing SenseMaking procedures like (1) effectuation, (2) triangulation, (3) affiliation, (4) deliberation, and (5) consolidation. More particularly, he argued that the ways in which procedures and systems are designed and implemented do not support these SenseMaking mechanisms. For instance, IS are not designed – either by system designers or managers – for social comparison through personal affiliation, to allow deliberation before taking action, nor to consolidate cumulative learning (Rice & Contractor, 1990). Weick and Meader (1993) have applied an updated version of Weick's 1985 framework to the design of Group Support Systems; Gephart (2004) examined SenseMaking in computer-mediated communications; Landgren (2005) relied on it for deriving design criteria for IS used in emergency response systems.

5.2.1.2 IS Support for SenseMaking

Building on Weick and Meader (1993) and their observations in connection to Group Support Systems (GSS) research, we posit that the study of the process of group problem should pay attention to the stage of SenseMaking of the problem itself. This crucial stage is often – but wrongfully – taken for granted and in an overambitious attempt of avoiding Type I and Type II errors, a Type III error will occur. Therefore we build on the idea developed by Weick (1985) that data processing capacity can be fully operational only when the IS user is capable of SenseMaking, able to "*connect the details and see what they might mean*" (Weick, 1985, p. 52). However, we want to take Weick's conclusion one step further by placing the source of this SenseMaking within the IS and not in its environment: metaphors, corporate culture, archetypes, myths, history.

For this reason we argue that systems are needed that are designed in line with users' mental model. We believe that the design of such an IS should encourage and support the SenseMaking process. In practice, however, it can be noticed that IS design does the opposite because it aims at replacing or suppressing the possibility to 'make sense' of situations. IS are designed according to three leitmotifs (Muhren et al., 2008a):

- A first building block is that IS research and practice, heavily inspired by Herbert Simon's work, use *structured data* as a substitute for information (Boland 1987). However, information is not a commodity; it is a skilled human accomplishment. Information is *meaning* resulting from a person's engagement with data (e.g. Davenport & Prusak 1998). In line with SenseMaking, IS should thus be designed to take dialogue, interpretation and an individual's search for meaning as sacred (Boland 1987).
- Another stronghold of IS design is the traditional hierarchy of information processing: the progression of data into information, information into knowledge, and knowledge into wisdom (Ackoff 1989). However, SenseMaking theory provides insights that this is not correct. There is neither a clear beginning nor end to the SenseMaking process (Klein et al. 2006). In the traditional hierarchy, data is perceived to be the starting point, but there is no data unless someone has created it using his or her knowledge (Tuomi 1999).
- A third worn model is that of IS as a 'repository of best practice' (Boland & Yoo 2003) which puts an emphasis on data storage. However, more information does not automatically lead to better SenseMaking (Klein et al. 2006). SenseMaking should not be viewed as a setting in which people need more information. The central problem requiring SenseMaking is mostly that there are too many potential meanings, not too

few (Weick 1995). What becomes important in the SenseMaking view is the issue how systems (in the largest sense) allow their users (again, in the largest sense) to "*access information, to conduct exchange, and to communicate in ways that foster mutual-personal relations*" (Woodward, 2001, p. 283). We can learn from this for the way future IS could be designed.

The conclusion can be no other than that the current leitmotif in IS design lacks a reflection on the nature of information technology (Orlikowski & Robey, 1991) and could do with a strong antidote against a tendency towards oversimplification.

5.2.1.3 Fitting is Enactment

Orlikowski and Robey (1991, p. 151) have pointed out that users often continually shape and reshape applications, so that technology ceases to be a fixed, tangible constraint. It is enactment in the purest sense. Information technology, by providing a means of representing reality through its set of concepts and symbols, provides a set of interpretive schemes through which people make sense of situation. IS institutionalize those interpretive schemes—those stocks of knowledge—by formalizing and encoding them, making them standardized, shared and taken for granted. Information technology contributes to the signification order by objectifying and reifying human actors' knowledge and assumptions, reinforcing them over time. "*When a person is able to connect the details and see what they might mean, processing capacity is restored. Meanings that can impose some sense on detail typically come from sources outside the electronic cosmos — sources such as metaphors, corporate culture, archetypes, myths, history. The electronic world makes sense only when people are able to reach outside that world for qualitatively different images that can flesh out cryptic representations. Managers who fail to cultivate and respect these added sources of meaning, and bring them to terminals, will make it impossible for people who work at screens to accurately diagnose the problems they are expected to solve*" (Weick, 1985, p. 52).

6 Structure

This section deals with some of the structural dimensions of organizing. [63] We subsequently deal with the alleged duality between procedure and improvisation (6.1) and the physical organization (6.2).

One of the most important structural dimensions of organizing is the way work is organized physically. Three aspects thereof come to mind: physical proximity (6.2.1), team size (6.2.2) and work load and time allocation (6.2.3). Although HRO literature so far has not dealt with these aspects, we posit that incorporating them into the research framework may be adding value to HRO research by putting HRO properties in a new perspective.

6.1 Procedure

Organizations spend a great deal of time and effort in developing, implementing and complying to procedures. Nevertheless, it seems an ironclad rule that procedures are deviated from. In this section we make a start with studying the mechanisms behind the compliance to and deviation from procedure. First, we describe what Standard Operating Procedures are (6.1.1). Next, we examine what is meant by improvisation (6.1.2). We conclude with looking into why and how people deviate from procedure (6.1.3).

6.1.1 Standard Operating Procedure

Under the Total Quality Paradigm, Standard Operating Procedures (SOPs) are generally considered good practice and a core competence of the quality enhancing organization: straightforward and well programmed. The only decision is which SOP to apply, meaning that there is only routine decision making. This view is in line with organizations "*coming close to meeting the conditions of closed rational systems, i.e., a well-buffered, well-understood technical core requiring consistency and stability for effective, failure-free operations*" (La Porte & Consolini, 1991, p. 24). An important advantage of such stable routine action is the reduced cognitive demands that such behavior entails (Cohen, Dosi, Egidi, Marengo, & Warglien, 1996). The underlying assumption is that of bounded rationality, namely that attention is scarce and thus costly and that the more things an organization can do routinely and in the absence of mindfulness, the more it can conserve attention for what really matters (Levinthal & Rerup, 2006, p. 509). In this respect, mindlessness can be an option too. Nevertheless, despite the benefits of a linear application of a priori well-designed procedures, there is an inherent danger in too strong a confidence in procedures: "*When an organization succeeds, its managers usually attribute success to themselves or at least to their organization, rather than to luck. The organization's members grow more confident of their own abilities, of their manager's skills, and of their organization's existing programs and procedures. They trust the procedures to keep them appraised of developing problems, in the belief that these procedures focus on the most important events and ignore the least significant ones*" (Starbuck & Milliken, 1988, p. 329-330). In this lies a warning against hubris and overlying simplification and reduction of reality, a warning that HROs take seriously. In that sense, HROs take a more nuanced stance towards the application of procedures. The following quote from Schulman makes clear how HROs differentiate from non-HROs in this respect: "*Consider briefly two theories of reliability that could be applied to the reliability of complex, hazardous operations […] Under one theory, reliability would stem from a constant, certain, predictable set of performances. All system conditions would be fully specified and anticipated. Term this the 'anticipatory model' of reliability – an approach that equates reliability to invariance. Here an organization ought to determine its functions, or at least strive to determine them, unambiguously and completely. Once 'correct' job reliability is specified, it should be 'locked in' once and for all through formal procedures, unvaryingly applied. A unified chain of command guarantees swift action and preserves the 'perfect' model. But a second approach to reliability is possible. Here reliability would be equated not with invariance but with resilience. Being responsive, rather than trying to weed out, the unexpected would be the ultimate safeguard of stable reliability. Despite the knowledge and elaborate procedures of an organization, its technology, it would be believed, is still capable of surprises. This expectation of surprise would not only be a state of mind, it would be recognized as an important organizational resource. Under this model of reliability, an organization would value its capacity for real-time discovery as much as its ability to control by anticipation*" (Schulman, 1993b, p. 368). This quote nicely depicts this subsection's contribution: what is the balance between procedure and improvisation?

6.1.2 Improvisation

It is generally assumed that organizations operate either according to procedures and routines (Adler & Borys, 1996) or in a more creative, improvised way (Barrett, 1998;Weick, 1998;Zack, 2000). This dichotomy however, is merely a hypothetical one as organizations do not operate in either of these ideal modes (Zack, 2000). In Chapter 2, we discussed the impossibility for an HRO to learn by trial and error, making it necessary to develop proactive abilities in managing risk. Thinking in advance and '*thinking the unthinkable*' is one way of describing what is meant by being proactive. Such an attitude calls for imagination and improvisation. Learning and feedback from small errors, incidents and near misses, simulations and emergency preparedness are examples of reliability activities based on imagination (Aase & Nybø, 2002). Improvisation can be defined in several ways: "*bringing one's personal awareness 'into the moment', and on developing a profound understanding for the action one is doing. This fusion of 'awareness' and 'understanding' brings the practitioner to the point where he or she can act with a range of options that best fit the situation, even if he or she has never experienced a similar situation*" (Mirvis, 1998). A noteworthy definition of improvisation is 'planning as action unfolds' (Weick cited in: Clegg et al., 2002). Improvisation is a kind of synthesis between the expected and unexpected circumstances, however without replacing either of them. Improvisation is enacted in the relationship between them but it does not replace the bi-directional relationship between poles (Figure 4.6).

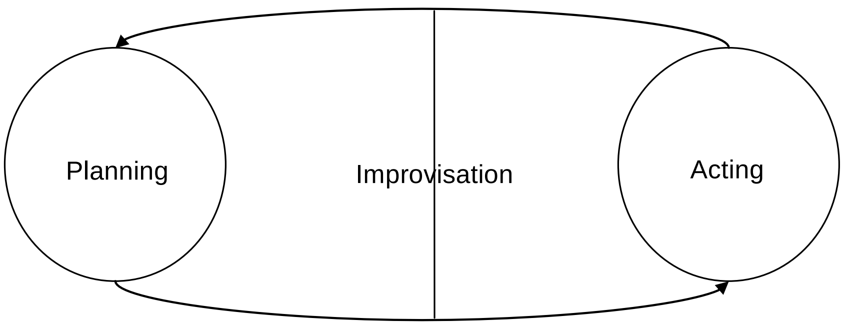

Figure 4.6 - Planning, Action and their Improvisation Synthesis (Clegg et al., 2002, p. 489)

Improvisation takes at least two things: experience and creativity (Levinthal & Rerup, 2006, p. 506). For this reason it is a false dichotomy however to state that organizations choose to behave either through improvisation or routine-based. In practice, they operate under both modes, depending on the situation (Brown & Eisenhardt, 1997). This is particularly true in case of HROs where experiential learning prior to action provides the necessary experience or building blocks, whereas mindfulness in action brings together experience and creativity (Levinthal & Rerup, 2006, p. 506). "*When encountering new problems, old ideas embedded in existing prototypes are often rediscovered as useful because they remind brokers of specific solutions embedded in particular designs*" (Levinthal & Rerup, 2006, p. 505).

6.1.3 Deviation from procedure

Throughout the debate, the question remains in which circumstances SOP or improvisation yields the best result. And to which degree, and how it should be administered.

In Chapter 1 we have already introduced several issues that are related to the study of Complexity. In the following paragraphs we go into these questions, since the complexity notion is essential for answering the Procedure vs. Improvisation question. We do so by relying on a set of frameworks: (1) the distinction between complex and complicated (Bennet & Bennet, 2004),

(2) the distinction between foreseeable and not foreseeable, and (3) the distinction between decision making and sense making. However, since they also constitute ‘tools’ that serve us well to gain insight in other issues than the application of procedures, we have chosen to present them as separate sections, on the same level as the SOP level they are capable of explaining.

Organizations are most of the time loosely coupled, and only become tightly coupled at particular moments of time. Nevertheless, they are designed in an all-purpose tightly coupled way. This is not workable in the loosely coupled time-periods and therefore organizational units will start developing alternative procedures. That works fine: the *floor* is happy and management is happy because success is visible. Then the system gets tightly coupled (domino effect) and fails. This mechanism is called *Practical Drift*: the slow, steady uncoupling of local practice from written procedure (Snook, 2002, p. 194). “*It is this structural tendency for subunits to drift away from globally synchronized rule-based Logics of Action toward locally determined task-based procedures that places complex organizations at risk*” (Snook, 2002, note 2, at p. 24). Globally untoward action is justified by locally acceptable procedure (Leveson, 2002, p. 182). “*… locally efficient procedures acquired through practice gain legitimacy through unremarkable repetition. If such emergent actions survive long enough without interfering with global interests, and if local procedures are successfully repeated consequence, they stand a good chance of becoming accepted practice*” (Leveson, 2002, p. 182).

6.2 Physical organization

6.2.1 Proximity

From an HRO perspective, physical proximity is an important component of reliability. Both the literature and common observation seem to suggest that individuals are most likely to interact and communicate with others when the physical characteristics of buildings or settings encourage them to do so (Pinto, Pinto, & Prescott, 1993, p. 1285). Although research on propinquity among team members is not totally conclusive, it is assumed that it is useful for enhancing communication flows among team members and can be an effective tool in creating supportive group relationships and improved communication flows (Pinto et al., 1993, p. 1285-1286). Kraut et al. (2002) have illustrated how collocation and face-to-face communication, make collaboration easier to accomplish among people who are collocated than among those who are apart: communication will be more social, less focused on the topic at hand, less planned, more ambiguous, and less likely to contain misunderstandings than communication conducted from a distance. The reason that comes to mind is the role of eye contact, which serves a number of different functions in encounters, one of which is gathering feedback on the other person’s reactions. Eye contact is also linked to affiliative motivation, and that approach and avoidance forces produce an equilibrium level of physical proximity, eye contact and other aspects of intimacy. If one of these is disturbed, compensatory changes may occur along the other dimensions (Argyle & Dean, 1965, p. 289).

Olson and Olson, for instance, have reported that groups with high common ground and loosely coupled work, with readiness both for collaboration and collaboration technology, have a chance at succeeding with remote work but that deviations from each of these create strain on the relationships among team members and require changes in the work or processes of collaboration to succeed. When they do not succeed, it is because distance often still matters (Olson & Olson, 2000).

For these reasons the efficacy of imitating face-to-face communication is an unquestioned presupposition of most current work on supporting communications in electronic media, an assumption challenged however by Hollan and Stornetta (1992) and Turoff et al (Turoff, Hiltz, Bahgat, & Rana, 1993). Research suggests that frequency of dispersion and/or geographic distance (1) negatively affect communication intensity and coordination effectiveness; (2) contribute to a perception of people as being less trustworthy and dependable; (3) negatively impact reliability effectiveness (van Fenema, 2002, p. 126-127); (4) increase stress; and (5) reduce job satisfaction (Monge, Rothman, Eisenberg, Miller, & Kirste, 1985). Traditional HROs have the advantage of physical proximity (Grabowski & Roberts, 1999), something virtual organizations have not. Workload

6.2.2 Team size

Research has long considered size as an important issue in research on teams (Campion, Papper, & Medsker, 1996) since team size and composition affect the team processes and outcomes. The optimal size (and composition) of teams is debated and will vary depending on the task. Research in the automotive industry for instance has been able to demonstrate only a small-to-negligible influence of team size on reliability (Pearce & Herbik, 2004), whereas other settings do indicate a substantial influence. Members of larger teams seem to be less satisfied, participate less, and cooperate less than members of smaller teams. With increases in team size, the psychological distance between individuals can increase.

6.2.3 Workload and time allocation

Workload is the relationship between a group or individual human operator and task demands. It is the amount of work or of working time expected or assigned. It is the perceived relationship between the amount of mental processing capability or resources and the amount required by the task (Hart & Staveland, 1988). The relationship between workload and reliability is not univocal. As workload increases, reliability does not necessarily decrease. Nachreiner (1995) reports that permanent low workload (underload) can lead to boredom, loss of situation awareness and reduced alertness. In addition, as workload increases reliability may not decrease as the operator may have a strategy for handling task demands.

These observations have their relevance from a HRO perspective that takes a nuanced view. HRO literature has for instance reported on the role of workload in relation to the property of Commitment to Resilience (Wilson, Burke, Priest, & Salas, 2005), adaptability (Xiao & Moss, 2001) and the system dynamic nature of the relationship between slack/loose coupling and workload (Cook & Rasmussen, 2005).

7 Requisite Variety

Organizations tend to simplify the complexity of their environment to the extreme. There are two reasons for this. A first reason is that organizations seem to be caught in a seeing homogeneity as a magic formula for success. Therefore, they strive for management dashboards and cockpits, fed by Key Reliability Indicators (KPIs) that are a synthesized reduction of reality; they consider team homogeneity as a management ideal; they strive for a total quality management that thrives on standardization and procedures; they design systems architectures that are transparent. These are all manifestations of an organization's drift to simplify to the extreme. A second reason for so much simplification is – contradictory enough – in the organization's success. Miller (1993) pointed out that success leads to simplification, i.e. a reduction of variety. This is because successful systems steadily become less sensitive to complex changes around them. This simplification concerns both the way reality is observed and the way an organization tends to homogenize its constituent parts, included its people. Nelson (2003), for instance, found by means of verbal network analysis that groups inter-organizationally hardly differ (in his case study between hospitals), but that there exist considerable intra-organizational differences between them. As a result, Nelson (2003, p. 5) rightly warns for an overambitious conclusion in terms of a globalization of organization structure and culture. Superficial similarities may hide deep differences.

The conclusion is that organizations could do with an antidote for so much reduction of reality. The principle of requisite variety could be a solution for this problem. Weick has elaborated this principle at length at several occasions but traces back to Ashby's Law of Requisite Variety (Ashby, 1958). In essence, the principle says that one needs variety to counter complexity. If one wants to construct a system able to deal with a high level of environmental variety, one has to provide a sufficiently high level of system variety (Ahlemeyer 2001). Bennet and Bennet (2004) are even more explicit when they state that for a complex system to survive in a complex environment, it must have greater variety than the environment (in areas that are relevant to the organization's health). On the other hand, they warn that too much variety can waste resources and lead to chaos and incoherence, but that too little variety may mean an inability to respond to complex situations. Optimize complexity of the present and deal with the anticipated future level (Bennet & Bennet 2005, p. 303).

7.1 Experience

It is logical to assume that the average number of years (experience) in the job, has an effect on a team's HRO and SeMa propensity. Also that it has an effect on its reliability. The experience that is needed for dealing with the unexpected shows itself when an individual starts improvising (Levinthal & Rerup, 2006). This is particularly true in case of HROs where experiential learning prior to action provides the necessary experience or building blocks, whereas mindfulness in action brings together experience and creativity (Levinthal & Rerup, 2006, p. 506). Also, it is the empiric experience that triggers learning. Together with the number of years, comes the witnessing of (near)misses and hence a higher level of Preoccupation with Failure.

7.2 Temporary staff

In a HRO context, requisite variety shows itself in more than way, for example in the choice for temporary staff. Vogus and Welbourne (2003a), drawing on Nemeth (1986) and Langer (1989), have reported skilled temporary employees stimulating divergence through processes of minority influence. The reason for this is that they stimulate the majority to exert more cognitive effort and think in more divergent ways. Vogus and Welbourne (2003a, p. 882-883) point out that from a HRO perspective, the use of temporary employees as a reliability-enhancing strategy is counterintuitive since it has been reported that inexperienced and untrained temporary workers have played a significant role in organizational accidents in several industries (Rousseau

& Libuser, 1997). However, the temporary employees and contractors in high-technology industries, like a Bank and a NPP, are highly trained and skilled.

7.3 Various Variances

The '*Various Variances*' notion is an umbrella term we have called into existence to label possible variety in all other constructs in our conceptual model. It is measured as the standard deviation, as opposed to the average scale on which all constructs primarily are measured. As such, *Various Variances* it is not a proper construct, but the *antipole* of all other constructs in the design. More particularly – but not solely – regarding the variance in in a team's HRO and SeMa propensity, we believe that the effect on reliability should be studied. Under contingency theory, team heterogeneity as well as team homogeneity have their value. Waterman (1990), for instance, argues that when team membership is too homogeneous, reliability usually suffers. The effect of such team heterogeneity or homogeneity is contingent on the circumstances. However, typical of contingency theory is that it remains unclear what, how and when this effect plays. Therefore we take an interest in studying the *tension between* and the *combined effect of* averages (homogeneity) and standard deviations (heterogeneity). Our findings have some relevance for practice as they may have the potential of fine-tuning the dosing of team homogeneity/heterogeneity composition. It can avoid a blind *all saisons approach* of making sure styles are diverse and complementary. On the one hand, such style diversity ensures that all perspectives on a problem are covered and different skills are brought to bear at stages of problem solving. On the other hand, greater diversity requires more time to be spent on acquaintance, team building, and conflict resolution, which all comes at considerable cost. (Waterman, 1990).

8 Reliability

As this study is about reliability, our independent variable is measured in terms of organizational reliability. Literature suggests a few sub-variables of reliability such as accuracy, effectiveness and efficiency (Lin & Carley, 2001). These may be interesting and theoretically different concepts, but in many cases, accuracy, effectiveness, and efficiency are indistinguishable (Lin & Carley, 2001). A second problem is that the measure of such reliability is a concept that "*in the real world is in many cases difficult to obtain, due to both the lack of information and the lack of consensus on this measure*" (Lin & Carley, 2001). We have chosen indicators of time to measure this organizational reliability: deadline alerts, closing time and their derivation, the relative number of incidents closed on time (expressed as a percentage). We believe that there should be other measures, but also that the ones we have chosen were practically the only ones that could be measured with the necessary scientific rigor. We are aware of the subjectivity of this choice. On the other hand, it is argued that "*[c]riteria for evaluating organizational effectiveness cannot be produced by some objective […] process. They are always normative and often controversial, and they are as varied as the theoretical models used to describe organizations and the constituencies that have some interest in their functioning […] We should not seek explanations for organizational effectiveness in general, since such general criteria are not available*"(Rochlin, 1993, p. 30).

These are measures of effectiveness, which is "*[…] both apex and abyss in organization behavior research. It is an apex in the sense that all conceptualizations and theories of organizations are* *aimed, ultimately, at identifying effective reliability. It is the fundamental dependent variable in organizational investigations, judgments of effectiveness and ineffectiveness are an inherent part of the activities of theoreticians, researchers, and practitioners in organizations. It is an abyss in the sense that no valid theories of organizational effectiveness exist in organizational behavior, and no list of criteria has ever been formulated that is either necessary or sufficient for evaluating the construct*" (Creed et al., 1993, p. 57). Creed et al. describe reliability as a subset of effectiveness (Creed et al., 1993, p. 60) and state that "*[T]o date, the link between reliability and effectiveness has not been adequately explored in the HRO research. Had it been, the possible position of HROs and reliability in a broader ranging contingent behavioral theory of the sort foreseen by Lewin and Minton (1986) could have been truly thought provoking*". As one of our objectives is to drive HRO research into mainstream management studies, we believe that the choice for a strong measurable and strongly measured operationalization of effectiveness may be indispensable. This is what has been lacking in the HRO research today.

The dependent variables as a proxy forreliability are a team's performance in the handling of urgent, respectively non-urgent incidents in time, i.e., according to what has been stipulated in the respective Service Level Agreements (SLA) (Table 3.4). These variables have been chosen because they meet the requirements of *Measures of Reliability*, i.e. quantities that describe system properties or mission requirements (Cothier & Levis, 1986). This choice is contestable, like any reliability measure would be contestable since there is no objective measure of organizational effectiveness (Creed et al., 1993, p. 58). The scores on the independent variables are assumed to reflect either directly or indirectly the cognitive activity of the participant (Smith, 1996, p. 262).

For this purpose we have examined the database of Incident Management module of Peregrine™ the Bank in which the incident management process is logged. we came up with the following reliability indicators:

PU12: Team performance regarding the handling of incidents of **U**rgency level **1** and **2**
(urgent incidents)

PU3: Team performance regarding the handling of incidents of **U**rgency level **3**
(non-urgent incidents)

PUA: Team performance of the handling of **A**ll incidents regardless of their **U**rgency level.

Also at the NPP, legacy data provided the numbers for team performance, as main dependant variable. For this purpose we have interrogated the Maintenance & Repair Process module of the SAP™ database regarding their reliability of teams in handling the notifications. This exercise lead to the following reliability indicators:

PU0: Team performance regarding the handling of incidents of **U**rgency level **0**
(urgent incidents). These are notifications that cannot be planned because of too short a time horizon – less than 3 weeks – the normal time it takes to get the work done according to the procedures. In the context of a NPP this time horizon is considered urgent.

PU123: Team performance regarding the handling of incidents of **U**rgency level **1**, **2** and **3** (non-urgent incidents) These are notifications that can and should be fully planned and dealt with through the incident registration system.

PUA: Team performance of the handling of **A**ll incidents regardless of their **U**rgency level.

PU123: Team performance regarding the handling of notifications of priority/Urgency 1, 2 and 3.

Noteworhty is that the organization is steering its members and unit towards these reliability measures that function as Key Reliability Indicators (KPI's). For instance, the Bank labels them as '*deadline alert*'. For the purpose of defining our dependent variable we have transposed them into an indicator (for urgent (PU12) and non-urgent (PU3) incidents respectively) that expresses the ratio of the number of incidents that is not in deadline alert over the total number of incidents a team has to handle. The Bank has set the norm for this deadline alert ratio to 95%, a norm that it does not manage to comply to in all its aspects. At the NPP, there is an implicit target ratio of 100%.

Chapter 5 Conceptual Model

A theory is something nobody believes,
except the person who made it.
An experiment is something everybody believes,
except the person who made it
– Unknown

1 Revised Conceptual Model

In line with the hermeneutics underlying our research, the testing of the a priori conceptual model and the theorizing described in the previous chapter has lead to the development of the reconceptualized model as shown in Figure 5.1.

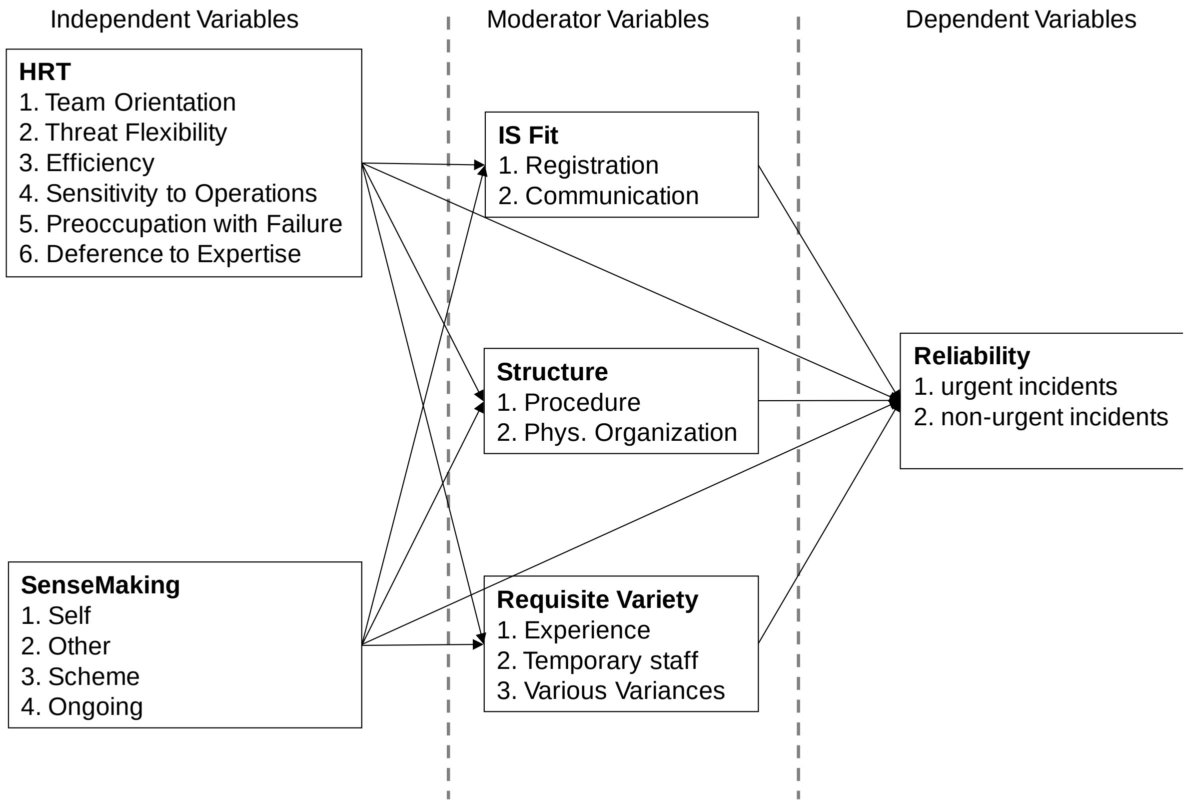

Figure 5.1 - Reconceptualized Model

Construct	*Sub-construct*	*Variable*	*Reference*
High Reliability Theory	Team Orientation	Factor Team Orientation	(Rasker, 2002;Burke, Wilson, & Salas, 2005)
	Threat Flexibility	Factor Threat Flexibility	(Sutcliffe & Vogus, 2003;Carroll & Edmondson, 2002)
	Efficiency	Factor Efficiency	(Heimann, 2005;Denrell, 2006;Ostroff & Schmitt, 1993)
	Sensitivity to Operations	Factor Sensitivity to Operations	(Weick & Sutcliffe, 2001)
	Preoccupation with Failure	Factor Preoccupation with Failure	(Weick & Sutcliffe, 2001)
	Deference to Expertise	Factor Deference to Expertise	(Weick & Sutcliffe, 2001)
SenseMaking	Self,	Factor Self	(Weick, 1995)
	Other	Factor Other	(Weick, 1995)
	Scheme	Factor Scheme	(Weick, 1995)
	Enactment	When handling an incident, I proceed step by step. I adjust my action en cours de route.	(Weick, 1995)
IS Fit	Registration	How often (measured as a percentage) do you use Peregrine/*SAP* for the registration /co-ordination/escalation/closing of an incident?	(Po-An Hsieh & Wang, 2007)
		How often (measured as a percentage) do you register quasi immediately the necessary data in Peregrine/*SAP*?	Ibid.
	Communication media	Face-to-face communication	(Daft & Lengel, 1986) (Brusoni & Prencipe, 2005)
		Telephone/Cell phone communication	Ibid.
		e-mail communication	Ibid.
		Peregrine/*SAP*	Ibid.
		Ratio non dedicated IS vs. dedicated IS [calculated field]	Ibid.
		Ratio voice supportive vs. non-voice supportive communication [calculated field]	Ibid.
		Ratio face vs. distance communication [calculated field]	Ibid.
Requisite Variety	Temporary staff	Are you an internal or external staff member?	(Vogus & Welbourne, 2003a)
	Gender	What is your sex?	(Milliken & Martins, 1996)
	Experience	How many years of experience do you have regarding incident handling?	

Construct	*Sub-construct*	*Variable*	*Reference*
Structure	Physical location	Where is your work spot?	(Grabowski & Roberts, 1997)
	Size	Team Size	(Rasker, 2002)
	Time allocation	How much of your time (percentage) do you spend on incident handling?	
		Mean number of urgent incidents per team member	
		Mean number of non-urgent incidents per team member	
		Mean number of incidents per team member	

Table 5.1 - Operationalizing the constructs

2 Propositions and Hypotheses

Contingency theory differs from other theories in the specific form of the propositions (Drazin & van de Ven, 1985). "*In a congruent proposition a simple unconditional association is hypothesized to exist among variables in the model; for example, the greater the task uncertainty, the more complex the structure. A contingent proposition is more complex, because a conditional association of two or more independent variables with a dependent outcome is hypothesized and directly subjected to an empirical test; for example, task uncertainty interacts with structural complexity to affect reliability. Central to a structural contingency theory is the proposition that the structure and process of an organization must fit its context (characteristics of the organization's culture, environment, technology, size, or task), if it is to survive or be effective. In a contingency theory, organizational reliability depends on the fit between organization context and structure and process – given that normal assumptions hold about the premises, boundaries, and system states derived from the theory*" (Drazin & van de Ven, 1985, p. 514-515). This hallmark of contingency theory forms the basis for the conceptual model underlying our research and explains in part its complexity and stratification. Based on the reconceptualization presented in the previous chapter, we defined possible gaps – contradictions and paradoxes – for which an in-depth study holds promising contributions to the HRO discipline. We describe these gaps as research issues in form of propositions, and this regarding the two aforementioned research questions.

2.1 Research Question 1

A proposition expressed by high reliability theorists, is the implicit supposition that not all organization types exhibit High Reliability characteristics to the same extent, with HRO archetypes (like nuclear power plants) at one end of the spectrum. The undefined other end of the spectrum however is more worrisome because as long as there is no research on what could be labeled non-HRO's, research into high reliability is difficult and only partial. Therefore, we identify blind spots of this continuum by comparing a nuclear power plant – as an HRO archetype – to the IT department of a financial institution, as a so-called *garden variety* (Roberts, 1993) or high reliability seeking (Vogus & Welbourne, 2003a) organization. This choice is not arbitrarily since the IT department of a Bank has many characteristics in common with a Nuclear Power Plant (Table 5.2). The risk of failure is very real since IT is operating under conditions of tight-coupling and interactive complexity (Perrow, 1999) and that the impact of such failure is very high.

1. Both represent important economic sectors where stakes are high in terms of investment and expected return (shareholder value)
2. Both are characterized by a spillover effect in case of a calamity: Effects do not stop at the boundaries of the respective organizations, neither at the frontiers of the countries in which the calamity occurs. Radioactive elements will be dispersed on an international scale and a major Bank failure might/will result in a domino effect that takes other institutions down too. The laws of physics (nuclear) and the laws of psychology (Banking) are universal. Moreover, because of a globalization tendency, both nuclear and financial incidents also have a considerable impact on the economic tissue of the world. Reasons are both tangible and intangible.
3. Both have the same reliance on technology resulting in the same weaknesses and threats: (a) aging of the technology (reactors or mainframe) (b) aging of employees (retirements) (c) a (blind) overreliance on technology might lead to catastrophe (d) a remarkable track record in terms of reliability and reliability might lead to hubris (overconfidence)
4. A body of national (e.g. Nuclear Control Agencies/ Commissions for Banking and Finance) and international organizations (Bank for International Settlements (finance)/International Atomic Energy Agency (nuclear)) is in place.

Table 5.2 - Resemblance between the Nuclear and the Financial sector

A NPP and a Bank are what would be labeled by Schulman a form of *holistic high reliability organization* (as opposed to a *decomposable HRO*) (Schulman, 1993a). The following quote by Schulman makes this clear: "*The technology of a nuclear power in existing plant designs does not readily allow itself to be simplified for safety. An air traffic control network as we have seen can be decomposed to reach safety, was when traffic is kept out of a sector, separations are increased, or planes are denied clearance to take off. An automatic reactor shut down or 'trip', however, is in many respects a riskier mode than is continuous operation of the reactor. The full operational integrity of a variety of valve and pumping systems is necessary to relieve pressures and carry off heat from the core*" (Schulman, 1993a, p. 42-43). In the same way, the systems of a financial institution cannot be simplified accept if one is willing to accept an excessive loss in usability, efficiency and even effectiveness. The power of the Information System is based on its potential of integrating processes. The upside risk and downside risk are definitely out of balance.

No organization is a pure type (Schulman, 1993a, p. 52): "*Even in a highly decomposable*[64] *organization there are structures of integrating authority and examples of overarching analysis that come into play in the solution of critical problems. Even in the most highly integrated, holistic organization, there will be examples of individualized initiative and action taken to save the day*" (Schulman, 1993a, p. 52).

One way of finding an answer to the resemblance of a NPP and the IT process of a Bank is by looking for a similar HRO propensity between both. Can we find the same constructs in both organizations? And also: Can we find them to the same degree?

We posit that the HRO properties will be present in both organization types as they are generally recognizable because of their high face validity. HRO properties are a translation and interpretation of contextual and structural dimensions (Pugh et al., 1968) of organizations and therefore will be distinguishable as such.

Therefore, our first proposition becomes:

Proposition 1-1: HRO properties are not unique, but HRO propensity levels are

H1-1: HRO properties will be discernible in the archetypical HRO (NPP) as well as in the mainstream High Reliability Seeking organization (Bank).

However, what makes HRO unique is the degree to which they score on these properties. Therefore, we posit that the archetypical HRO exhibits a higher score on these properties than will the non-archetypical HRO.

Hence, the following research proposition:

Proposition 1-2: The non-archetypical HRO the Bank) exhibits the same HRO characteristics as the archetypical HRO (like the NPP) but to a lesser extent.

The corresponding hypotheses become:

H1-2a: The average HRO propensity at the Bank is lower than at the NPP

H1-2b: The average Team Orientation at the Bank is lower than at the NPP

H1-2c: The average Threat Flexibility at the Bank is lower than at the NPP

H1-2d: The average Preoccupation with Failure at the Bank is lower than at the NPP

H1-2e: The average Sensitivity to Operations at the Bank is lower than at the NPP

H1-2f: The average Deference to Expertise at the Bank is lower than at the NPP

In line with HRO literature (Roberts, 1990b;Klein et al., 1995) we see that HROs value requisite variety regarding several aspects (experience, gender, skills, prior professional career …). Therefore, we propose that this should be reflected in their HRO propensity. Hence, the next two proposition become:

Proposition 1-3: The higher the requisite variety of a team, the higher its HRO propensity

This results in the following hypotheses:

H1-3a: Teams using richer media exhibit a higher HRO propensity.

H1-3b: More experienced teams exhibit a higher HRO propensity.

Propostion 1-4**:** The higher the requisite variety of a team, the higher its SeMa propensity

H1-4a: Teams using richer media exhibit a higher SeMa propensity.

H1-4b: More experienced teams exhibit a higher SeMa propensity

Remarkably enough, this variety is not requisite in the domain of HRO propensity itself. There the implicit rule of thumb is: the more staff shares these same values, the more reliable they will be as a team or organization. Put differently: the smaller the variance in HRO propensity, the higher the reliability. This leads us to the following research proposition:

Proposition 1-5: The non-archetypical HRO (the Bank) exhibits the same HRO characteristics as the archetypical HRO (the NPP) but exhibits a lower variance.

As we have argued at the beginning of this chapter, the general belief is that for an organization (or subunit) homogeneity in terms of HRO propensity is better than heterogeneity. For instance, teams that exhibit a low variance in the degree of orientation towards Reluctance to Simplify are supposed to be better than teams exhibiting a higher variance. This is remarkable the more so because it opposes the notion of requisite variety.

The argument we develop is that for high reliability (synthesis) to emerge, HRO propensity (thesis) needs to be challenged by a critical, diverging HRO propensity and behavior (antithesis). This is a plea for not pursuing a strategy of univocal HRO propensity but for pursuing a strategy, that fosters deviant behavior vis-à-vis HRO propensity. Such deviance is the antidote that provides the HRO potion with its therapeutic effect. A monolithic HRO therefore would go solid. To avoid this from happening, an organization must continuously and simultaneously step on the gas and brake. To put it metaphorically: in the same way as a tank – despite its unwieldiness – can make a U-turn at a spectacular speed by stepping on the gas for one caterpillar track while slamming on the brakes of the other caterpillar track, an organization derives it robustness – the combination of stability and flexibility – from a balanced heterogeneity.

With the NPP as an HRO archetype and the Bank as an example of a garden variety HRO, we posit therefore that the NPP exhibits a higher degree of heterogeneity in terms of HRO propensity. Taking the standard deviation as a measure of this variance (spread), we come to the following hypotheses:

H1-5a: The variance in HRO propensity at the Bank is lower than at the NPP

H1-5b: The variance in Team Orientation at the Bank is lower than at the NPP

H1-5c: The variance in Threat Flexibility at the Bank is lower than at the NPP

H1-5d: The variance in Preoccupation with Failure at the Bank is lower than at the NPP

H1-5e: The variance Sensitivity to Operations at the Bank is lower than at the NPP

H1-5f: The variance Deference to Expertise at the Bank is lower than at the NPP

In line with the argumentation built above, the same proposition (mutatis mutandis) can be formulated regarding the SenseMaking propensity. The next propostion therefore becomes:

Proposition 1-6: The non-archetypical HRO the Bank) exhibits the same SeMa characteristics as the archetypical HRO (the NPP) but exhibits a lower variance.

H1-6a: The variance in SenseMaking propensity at the Bank is lower than at the NPP

H1-6b: The variance in Self propensity at the Bank is lower than at the NPP

H1-6c: The variance in Other propensity at the Bank is lower than at the NPP

H1-6d: The variance in Scheme propensity at the Bank is lower than at the NPP

In the same philosophy of acknowledging paradox, we formulate the next proposition:

Proposition 1-7: The constructs of Mindfulness and Resilience interrelate

HRO literature seems to presupose there is no multicollinearity between the HRO properties. It is our assertion that this is not univocally so, since from a previous research phase we have learned that the constructs are highly correlated.[65] Especially regarding the mutual influence between the constructs of Preoccupation with Failure and Deference to expertise, we hypothesize a strong negative correlation. In other words: Mindfulness (i.e. *pars pro toto* Preoccupation with Failure) is the enemy of Resiience (i.e. *pars pro toto* Deference to Expertise). An organization that tries to be mindful has a good (better) chance of being stable in the short run because it avoids intrusions on its processes. The organization is not endangered and can continue to operate as it is used to, ‘business as usual’. An organization that tries to be resilient, on the other hand, has a better chance of being stable in the end because it has learnt how to deal with intrusions in its processes. The relationship between Mindfulness and Resilience is not univocal. Hence, it is also more interesting and useful Mindfulness and resilience cannot live with each other, but neither can they live without each other.

The hypothesis hence becomes:

H1-7a: The higher a team’s Preoccupation with Failure, the lower its Deference to Expertise.

In the same line of thought, another hypothesis relates to the conditions that are necessary for mindfulness and resilience to take effect. The question arises how one can be resilient without being mindful. We posit that it is very unlikely that someone (or a team) can be resilient without being mindful. Therefore, we hypothesize that:

H1-7b: Being mindful is a prerequisite for being resilient.

Faithful to our assumption that a NPP is an example of an HRO archetype, whereas a Bank is an example of a mainstream organization, we come to the following proposition and hypothesis:

Proposition 1-8: The NPP is more reliable than the Bank

H1-8: The NPP is more reliable than the Bank.

2.2 Research Question 2

In the second place, the research aims at validating the positive influence of HRT and SeMa constructs on process reliability. In other words: we want to test the assertion that HRO and SeMa Propensities will yield high reliability [RQ2].

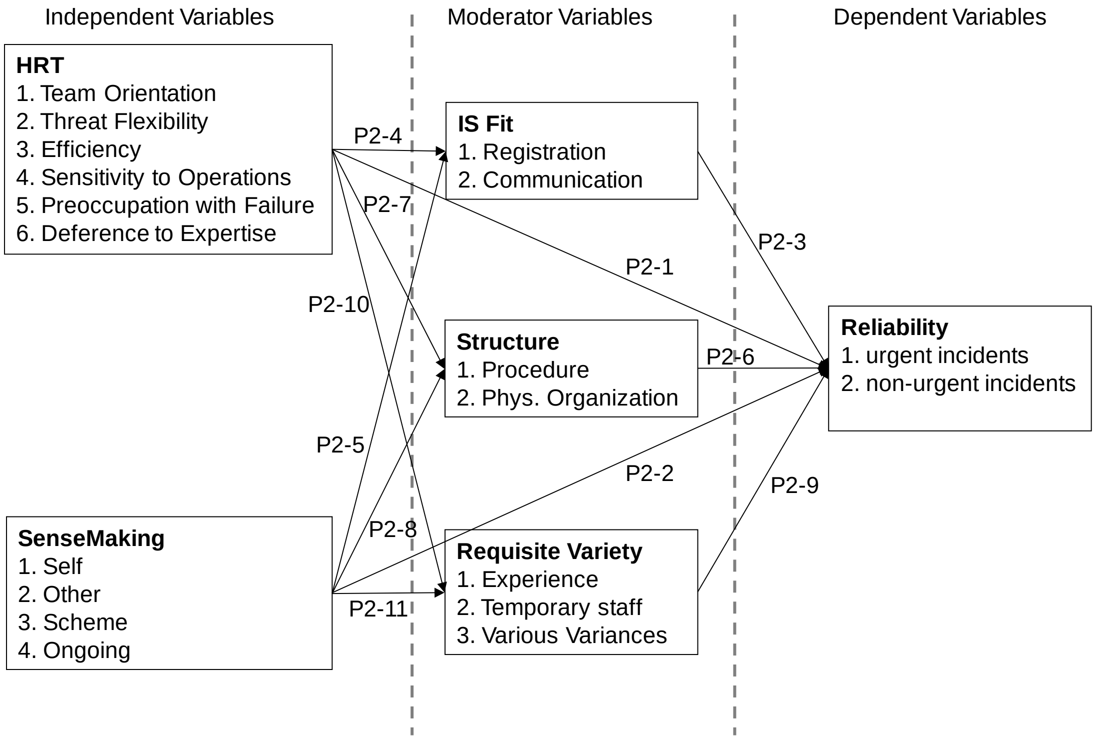

Figure 5.2 - Propositions for RQ2

The second analysis level is a further exploration of the first level. It will help considerably in gaining a better understanding of the traits of HROs, but it cannot provide an explanation, apart from what is theorized in conceptual literature on the subject.

The research propositions are indicated in the conceptual model shown in Figure 5.2 and their formulation together with an enumeration of the underlying constructs shown in Table 5.3.

Propostion	Constructs			Desription
P2-1	HRT		Reliability	The higher the HRO propensity, the higher the reliability.
P2-2	SeMa		Reliability	The higher the SeMa propensity, the higher the reliability.
P2-3		IS Fit	Reliability	The lower the use of the dedicated IS, the higher the reliability.
P2-4	HRT	IS Fit	Reliability	The better the fit between HRO propensity and IS use, the higher the reliability.
P2-5	SeMa	IS Fit	Reliability	The better the fit between SeMa propensity and IS use, the higher the reliability.
P2-6		Structure	Reliability	The more balanced the structural organization dimension, the higher the reliability.
P2-7	HRT	Structure	Reliability	The better the fit between HRO propensity and the structural organization dimension use, the higher the reliability.

P2-8	SeMa	Structure	Reliability	The better the fit between SeMa propensity and the structural organization dimension use, the higher the reliability.
P2-9		Req. Variety	Reliability	The more balanced the variety, the higher the reliability.
P2-10	HRT	Req. Variety	Reliability	The better the fit between HRO propensity and variety, the higher the reliability.
P2-11	SeMa	Req. Variety	Reliability	The better the fit between SeMa propensity and variety, the higher the reliability.

Table 5.3 - Propositions and underlying constructs (RQ2)

Proposition 2-1 The higher the HRO propensity, the higher the reliability.

A shared mental model between team members (Rasker, 2002) increases team performance. This shared mental model corresponds to what we have labeled 'Team Orientation'. Rasker (2002) found that training team members in each others' tasks or positional rotation did *not* improve reliability. The reason put forward by Rasker is that such does not enhance thorough knowledge. However, teams have other characteristics contributing to high reliability. For instance, they serve as redundant systems to help trap and mitigate the consequences of errors (Burke et al., 2005). It has been argued that a team-based strategy towards reliability is the best way to transform a garden variety organization into an HRO (Burke et al., 2005). For this reason, we posit that an orientation on the team favors reliability because it is a prerequisite determinant of collective mindfulness and resilience. Therefore, we come to this hypothesis:

H2-1a: Teams exhibiting a higher propensity towards Team Orientation yield higher reliability in the handling of urgent incidents, whereas this is counterproductive for the handling of non-urgent incidents.

A caveat is in place: concerning the interrelation between dependent and independent variables: Despite the unproblematic and univocal character of the relationship between HRO propensity (as an independent variable) and team performance (as a dependent variable), it can be hypothesized that the sense of this relation is bidirectional. In line with findings from Myers and McPhee (2006) in their multilevel analysis of the influences on team member assimilation in a municipal fire department, we are aware of the possibility of a team's reliability influencing its HRO propensity[66]. The reason is that teams that perform well are likely to have higher levels of cohesiveness (Riddle, Anderson, & Martin, 2000), and members are likely to feel more involvement and connection with one another.

We argue that the provision of team information positively influences organizational reliability. In our study, such team information corresponds to the construct of Sensitivity to Operations. Therefore, the hypothesis we deduct from this can be expressed as follows:

H2-1b: Teams exhibiting a high propensity towards Team Orientation and exhibiting a high degree of Sensitivity to Operations yield a higher reliability than teams than the same teams exhibiting a low degree of Sensitivity to Operations.

Management tends to expand their control over the organization. The organization hence becomes more bureaucratic. What is suggested by literature on HROs is that the reflex of this kind of organization does not fit the conclusions from Threat Rigidity (Staw et al., 1981). Instead of becoming more bureaucratic, adhocratic and organic mechanisms seem to take over from mechanist ones. The organizational authority structure shifts in the sense that people in HROs increase their reliance on connections to other people (people-to-people links) and depend less on procedures (*sensu stricto*). They also have a wider access to resources (people-to-resources links).[67] [68] This characteristic has been described by Sutcliffe and Vogus (2003) as Threat Flexibility. The hypotheses hence become:

H2-1c: The higher the average Threat Flexibility, the higher the reliability.

H2-1d: Teams that operate in a less restrictive (more supportive) organizational climate perform better than teams that do not (Smith-Crowe, Burke, & Landis 2003).

H2-1e: Teams that operate in a less efficiency-driven (more slack) organizational climate perform better than teams that do not.

Proposition 2-2 The higher the SeMa propensity, the higher the reliability.

The same logic from above applies to the SeMa propensity. However, we examine not as much the average value of SeMa propensity (on the level of the root construct, Scheme and Ongoing, but the spread in observation SeMa propensity. We believe that the more diversity (i.e. variance) is present, the more reliable a team will be. The hypotheses hence become:

H2-2a: The higher the variance in SeMa propensity, the higher the reliability.

H2-2b: The higher the variance in Scheme, the higher the reliability.

H2-2c: The higher the variance in Ongoing, the higher the reliability.

Proposition 2-3 The lower the use of dedicated IS, the higher the reliability.

We posit that dedicated IS are not suited for reaching high reliability, unless there is a fit with user and environment characteristics. Therefore relying on more richer tools for incident handling (especially communication) is a better strategy. The hypothesis hence becomes:

H2-3: Teams using richer media are more reliable.

The next proposition elaborates on this insight.

Proposition 2-4 The better the fit between HRO propensity and IS use, the higher the reliability.

An essential requirement for the effective support of a process in natural and artificial systems is the structural and dynamic compatibility between the information processing system and the process it supports (Kampfner, 1998, p. 154). One way to guarantee this is by putting the user and his characteristics central. An adaptable IS is built with and from people. Human beings should be the bricks; the technology should be the mortar.

Which leads us to the following hypotheses:

H2-4a: Teams exhibiting a high propensity towards Team Orientation, relying on richer media yield a higher reliability.

H2-4b: Teams relying little on the dedicated IS and exhibiting a higher HRO propensity perform better than when they rely more on dedicated IS.

Proposition 2-5 The better the fit between SeMa propensity and IS use, the higher the reliability.

This proposition is in line with what we have hypothesized under Propostion 2-4.

H2-5: Teams relying little on the dedicated IS and exhibiting a higher SeMa propensity perform better than when they rely more on dedicated IS.

This hypothesis cannot be validated at an acceptable level of significance.

Proposition 2-6 The more balanced the structural organization dimension, the higher the reliability.

Working closer to each other, should be advantageous for reliability. SenseMaking and Mindfulness will be easier to achieve when distances are low. It can also be hypothesized that smaller teams will be more reliable than larger teams. From our interviews we have learned that also a higher workload is advantageous for reliability because scale will permit a more structured organization of the work-follow-up. The same applies to teams that are capable of spending more of their time to indicent handling (instead, e.g. on project work). The hypotheses hence become:

H2-6a: Teams that work under close physical proximity perform better than teams that do not.

H2-6b: Larger teams are more reliable than smaller teams.

H2-6c: Teams with higher incident workload are more reliable than teams with a lower workload.

H2-6d: Teams with a greater deal of their time allocated to incident management are more reliable than teams with smaller time allocation.

Proposition 2-7 The better the fit between HRO propensity and the structural organization dimension use, the higher the reliability.

It can be assumed that a higher HRO propensity will even increase reliability when the conditions regarding the physical work organization (Proposition 2-6) are met. The hypothesis hence becomes:

H2-7a: A high HRO propensity enhances the effect on reliability of teams working under close physical proximity

H2-7b: A high HRO propensity enhances the effect on reliability of larger teams

H2-7c: A high HRO propensity enhances the effect on reliability of teams with higher incident workload.

Proposition 2-8 The better the fit between SeMa propensity and the structural organization dimension use, the higher the reliability.

In the same way, the hypothesis regarding this propostion become:

H2-8a: A high SeMa propensity enhances the effect on reliability of teams working under close physical proximity

H2-8b: A high SeMa propensity enhances the effect on reliability of larger teams

Proposition 2-9 The more balanced the variety, the higher the reliability.

One obvious hypothesis is:

H2-9a: More experienced teams are more reliable.

More important however, is the requisite variety that exists within teams regarding all constructs in our model. It is this kind of requisite variety, our research wishes to focus on.

Like in all cases where paradox arises, it is good to come to realize that paradox is essential and good in keeping "*the organization on its toes, in a state of continuous awareness of its own contradictions*". However important, this is not sufficient when decisions have to be made and actions taken. Juxtaposing opposites may help people in becoming aware of the tensions and tradeoffs that go along with making choices (Clegg et al., 2002, p. 487).

We argue this is so because successful organizations tend to become simpler over time, not more complex (Miller, 1993). There are numerous factors that account for this, such as past success, overconfidence, and the way past experiences are viewed (Miller, 1993).

Another paradox is introduced by the notion of *Hyper vigilance*. Janis (1982b) describes this phenomenon as an excessive alertness to signs of threat or pressure. It is triggered by the time pressure and other stressful situations (Amabile, Mueller, Simpson, Hadley, Kramer, & Fleming, 2002, p. 4). In this respect, we hypothesize that it is conflicting with the need to be mindful. Two consequences can be drawn from this. It is a plea to take into account the time factor in any research on mindfulness. (Something that is reflected in our research by making a distinction between urgent incidents and non-urgent incidents.) Under time pressure, the access to tried-and-tested decision-making best practices seems to be mentally or physically obstructed. Problem definition, alternative generating, alternative analysis and deciding do not take place in depth or even not at all. The most conspicuous observation being that *Hypervigilance* leads to restricted information gathering and processing. Janis warns that this "*leads to ill-considered decisions that are frequently followed by post-decisional conflict and frustration*" (Janis, 1982b, p. 81). This same logic, applies to the other HRT constructs as well. We therefore become the following hypotheses:

H2-9b: The higher the variance in HRO propensity, the higher the reliability.

H2-9c: The higher the variance in Team Orientation, the higher the reliability.

H2-9d: The higher the variance in Threat Flexibility, the higher the reliability.

H2-9e: The higher the variance in Preoccupation with Failure, the higher the reliability.

H2-9f: The higher the variance in Sensitivity to Operations, the higher the reliability.

H2-9g: The higher the variance in Deference to Expertise, the higher the reliability.

Proposition 2-10 The better the fit between HRO propensity and variety, the higher the reliability.

Because of the strong consistency of these constructs of Threat Flexibility and Efficiency in the exploratory factor analysis we have performed, and therefore contrary to the previous proposition, we hypothesize:

H2-10a: Teams that perceive Threat Flexibility more homogenously perform better than teams that do not.

H2-10b: Teams that perceive efficiency drivenness more homogenously perform better than teams that do not.

Proposition 2-11 The better the fit between SeMa propensity and variety, the higher the reliability.

The hypothesis here becomes:

H2-11: More Eperienced teams, relying more on SeMa propensity, are more reliable.

2.3 Summary of propositions and hypotheses

Research Question 1	
Proposition 1-1:	HRO properties are not unique, but HRO propensity levels are
H1-1:	HRO properties will be discernible in the archetypical HRO (NPP) as well as in the mainstream High Reliability Seeking organization (Bank).
Proposition 1-2:	The non-archetypical HRO the Bank) exhibits the same HRO characteristics as the archetypical HRO (like the NPP) but to a lesser extent.
H1-2a:	The average HRO propensity at the Bank is lower than at the NPP
H1-2b:	The average Team Orientation at the Bank is lower than at the NPP
H1-2c:	The average Threat Flexibility at the Bank is lower than at the NPP

H1-2d:	The average Preoccupation with Failure at the Bank is lower than at the NPP
H1-2e:	The average Sensitivity to Operations at the Bank is lower than at the NPP
H1-2f:	The average Deference to Expertise at the Bank is lower than at the NPP
Proposition 1-3:	The higher the requisite variety of a team, the higher its HRO propensity
H1-3a:	Teams using richer media exhibit a higher HRO propensity.
H1-3b:	More experienced teams exhibit a higher HRO propensity.
***Propostion 1-4*:**	The higher the requisite variety of a team, the higher its SeMa propensity
H1-4a:	Teams using richer media exhibit a higher SeMa propensity.
H1-4b:	More experienced teams exhibit a higher SeMa propensity
Proposition 1-5:	The non-archetypical HRO the Bank) exhibits the same HRO characteristics as the archetypical HRO (the NPP) but exhibits a lower variance.
H1-5a:	The variance in HRO propensity at the Bank is lower than at the NPP
H1-5b:	The variance in Team Orientation at the Bank is lower than at the NPP
H1-5c:	The variance in Threat Flexibility at the Bank is lower than at the NPP
H1-5d:	The variance in Preoccupation with Failure at the Bank is lower than at the NPP
H1-5e:	The variance Sensitivity to Operations at the Bank is lower than at the NPP
H1-5f:	The variance Deference to Expertise at the Bank is lower than at the NPP
Proposition 1-6:	The non-archetypical HRO the Bank) exhibits the same SeMa characteristics as the archetypical HRO (the NPP) but exhibits a lower variance.
H1-6a:	The variance in SenseMaking propensity at the Bank is lower than at the NPP
H1-6b:	The variance in Self propensity at the Bank is lower than at the NPP
H1-6c:	The variance in Other propensity at the Bank is lower than at the NPP
H1-6d:	The variance in Scheme propensity at the Bank is lower than at the NPP

Proposition 1-7:	The constructs of Mindfulness and Resilience interrelate
H1-7a:	The higher a team's Preoccupation with Failure, the lower its Deference to Expertise.
H1-7b:	Being mindful is a prerequisite for being resilient.
Proposition 1-8:	The NPP is more reliable than the Bank
H1-8:	The NPP is more reliable than the Bank.

Table 5.4 - Summary of research propositions and hypotheses regarding Research Question 1

Research Question 2	
Proposition 2-1 :	The higher the HRO propensity, the higher the reliability.
H2-1a:	Teams exhibiting a higher propensity towards Team Orientation yield higher reliability in the handling of urgent incidents, whereas this is counterproductive for the handling of non-urgent incidents.
H2-1b:	Teams exhibiting a high propensity towards Team Orientation and exhibiting a high degree of Sensitivity to Operations yield a higher reliability than teams than the same teams exhibiting a low degree of Sensitivity to Operations.
H2-1c:	The higher the average Threat Flexibility, the higher the reliability.
H2-1d:	Teams that operate in a less restrictive (more supportive) organizational climate perform better than teams that do not (Smith-Crowe, Burke, & Landis 2003).
H2-1e:	Teams that operate in a less efficiency-driven (more slack) organizational climate perform better than teams that do not.
Proposition 2-2 :	The higher the SeMa propensity, the higher the reliability.
H2-2a:	The higher the variance in SeMa propensity, the higher the reliability.
H2-2b:	The higher the variance in Scheme, the higher the reliability.
H2-2c:	The higher the variance in Ongoing, the higher the reliability.
Proposition 2-3 :	The lower the use of dedicated IS, the higher the reliability.
H2-3:	Teams using richer media are more reliable.
Proposition 2-4:	The better the fit between HRO propensity and IS use, the higher the reliability.
H2-4a:	Teams exhibiting a high propensity towards Team Orientation, relying on richer media yield a higher reliability.

H2-4b: Teams relying little on the dedicated IS and exhibiting a higher HRO propensity perform better than when they rely more on dedicated IS.

Proposition 2-5: The better the fit between SeMa propensity and IS use, the higher the reliability.

H2-5: Teams relying little on the dedicated IS and exhibiting a higher SeMa propensity perform better than when they rely more on dedicated IS.

Proposition 2-6: The more balanced the structural organization dimension, the higher the reliability.

H2-6a: Teams that work under close physical proximity perform better than teams that do not.

H2-6b: Larger teams are more reliable than smaller teams.

H2-6c: Teams with higher incident workload are more reliable than teams with a lower workload.

H2-6d: Teams with a greater deal of their time allocated to incident management are more reliable than teams with smaller time allocation.

Proposition 2-7: The better the fit between HRO propensity and the structural organization dimension use, the higher the reliability.

H2-7a: A high HRO propensity enhances the effect on reliability of teams working under close physical proximity

H2-7b: A high HRO propensity enhances the effect on reliability of larger teams

H2-7c: A high HRO propensity enhances the effect on reliability of teams with higher incident workload.

Proposition 2-8: The better the fit between SeMa propensity and the structural organization dimension use, the higher the reliability.

H2-8a: A high SeMa propensity enhances the effect on reliability of teams working under close physical proximity

H2-8b: A high SeMa propensity enhances the effect on reliability of larger teams

Proposition 2-9 *:* The more balanced the variety, the higher the reliability.

H2-9a: More experienced teams are more reliable.

H2-9b: The higher the variance in HRO propensity, the higher the reliability.

H2-9c: The higher the variance in Team Orientation, the higher the reliability.

H2-9d: The higher the variance in Threat Flexibility, the higher the reliability.

H2-9e:	The higher the variance in Preoccupation with Failure, the higher the reliability.
H2-9f:	The higher the variance in Sensitivity to Operations, the higher the reliability.
H2-9g:	The higher the variance in Deference to Expertise, the higher the reliability.
Proposition 2-10:	The better the fit between HRO propensity and variety, the higher the reliability.
H2-10a:	Teams that perceive Threat Flexibility more homogenously perform better than teams that do not.
H2-10b:	Teams that perceive efficiency drivenness more homogenously perform better than teams that do not.
Proposition 2-11:	The better the fit between SeMa propensity and variety, the higher the reliability.
H2-11: More Eperienced teams, relying more on SeMa propensity, are more reliable.	

Table 5.5 - Summary of research propositions and hypotheses regarding Research Question 2

Chapter 6 Data Analysis

In the knowledge-based economy,
the role of the statistician is
to help people tell great stories.
Geoff Carss

In this chapter, we assess the conceptual mdoel developed in Chapter 5 and answer the two research questions raised in the Introduction (Chapter 1). First, we validate the reconceptualized model constructs as presented in chapter 4 (Section 1). Next, we address the question whether the organizations we study are HROs [RQ1]. We do so by comparing our two case studies (Section 2). Finally, we examine what constitutes high reliability [RQ2]. We do so by measuring the (high) reliability of our two case studies (Section 3).

1 Reconceptualized Model Construct Validation

The purpose of this section is to test the reconceptualized research model developed in this dissertation. To this end, we validate the constructs that are at the basis of our reconceptualized research model by subjecting the data to an exploratory factor analysis (1.1) and by testing the resulting factors to an internal consistency test (1.2).

1.1 Data reduction

We have used factor analysis to reduce various sets of items into a smaller number of compound factors. A full description of the factor analyses we conducted can be found under Appendix H (Bank Case) and Appendix I (NPP Case). All factors are extracted by Principal Component Analysis with Varimax rotation with Kaiser Normalization. We only performed such an analysis if the necessary conditions are met: KMO measure higher than 0.50 and a significant value of the Bartlett test (Poelmans, 2002, p. 135). The factors emerging from our analysis meet the exigency that they should explain for 60% of total Variance.

Our approach is in line with Koch's (1993) modus operandus. As a factor analysis with all the variables grouped did not give a desirable outcome, we first isolated the moderator items from the items relating to theory and we performed a factor analysis on the first set. Next, we chose to split the items in two sets: a set of items relating to theory (HRT and SeMa), and another set relating to the moderator variables. Some constructs could be labeled according to theoretical constructs and sub-constructs. For the factors relating to HRT, we refer to Weick et al. (1999). For the factors relating to Scheme, Self and Other, we specifically refer to our relabeling of SenseMaking in Chapter 4 (Reconceptualized model). Other constructs could not be labeled according to theoretical constructs and sub-constructs. For these factors we have chosen a new, best-fitting, label (e.g. Team Orientation). The factors with a sufficiently high internal consistency (Cronbach's alpha $\geq .60$) were aggregated in a compounded indicator. Next, the procedure was repeated for the items relating to SenseMaking.

The outcome of this reconceptualization process is shown in for the Bank Case and NPP Case respectively. For the background behind and interpretation of the labels of these newly found factors, we refer to the corresponding sections in Chapter 4, addressing the reconceptualization.

Construct	*N items*	*Items*	*Cronbach's Alpha*
Team Orientation	5	20.2 20.1 19.5 19.4 20.3	0.779
Preoccupation with Failure	5	15.1 15.3 14.4 15.2 15.4	0.695
Deference to Expertise	6	13.5 14.1 22.5 17.1 23.4 24.2	0.598
Sensitivity to Operations	2	20.5 20.4	0.812
Other	3	19.2 19.1 19.6 13.4	0.647
Self	2	13.1 13.2	0.557
Scheme	*3*	13.3 14.2 14.5	0.306
Threat Flexibility	4	24.1 22.3 17.2 23.3	0.576
Efficiency	2	24.4 22.1	0.605
Peregrine	2	10 9	0.821
Logics of Action	*3*	13.6 22.4 22.2	0.470
Deviation	*2*	24.3 14.3	0.266
HRT	18	20.2 20.1 19.5 19.4 20.3 15.1 15.3 14.4 15.2 15.4 13.5 14.1 22.5 17.1 23.4 24.2 20.5 20.4	0.806
SeMa	*9*	19.2 19.1 19.6 13.4 13.1 13.2 13.3 14.2 14.5	0.515

Table 6.1 - Item Composition and Scale Reliability of Bank Case Constructs

Construct	*N items*	*Items*	*Cronbach's Alpha*
Other	3	19.1 19.2 19.6	0.769
Self	2	13.1 13.2	*0.579*
Scheme	2	14.2 14.5	0.695
SeMa	7	13.1 13.2 14.2 14.5 19.2 19.1 19.6	0.688
Threat Flexibility	3	22.3 24.1 23.3	0.673
Self Efficacy	4	22.3 22.2 24.1 22.4	0.742
Efficiency	2	24.4 22.1	0.680
Pressure	3	24.4 22.1 14.3	0.643
Supplementary Resources	3	17.2 13.6 23.3	0.596
Team Orientation	4	19.4 19.5 20.2 20.1	0.860
Sensitivity to Operations	2	20.4 20.5	0.680
Preoccupation with Failure	5	15.1 14.4 15.2 15.3 15.4	0.807
Deference to Expertise	5	13.5 22.5 23.4 24.2 14.1	0.734
HRT	16	19.4 19.5 20.1 20.2 20.5 20.4 15.1 15.2 15.3 15.4 14.4 13.5 22.5 23.4 24.2 14.1	0.898

Table 6.2 - Item Composition and Scale Reliability of NPP Case Constructs

1.2 Scale validation

As a second step in the validation of reconceptualized model, its constructs internal validity was assessed. Cronbach's alphas were computed for each of the subscales. For the Bank Case (Table 6.1), their values ranged from 0.266 to 0.821. For the NPP Case (Table 6.2). Both tables regroup only those scales that have a sufficient internal consistency. In those cases in which the Cronbach's Alpha is less than 0.60, the composite variable is deemed unreliable and the individual items are used for further statistical analysis when relevant. This is different from Koch's choice to keep subscales with a disappointing Cronbach's alpha of 0.50 because of its major empirical importance (Koch, 1993, p. 88), we decided to take the general rule of taking 0.60 as a cutoff point. A few exceptions are those constructs with values for Cronbach's alpha approaching the .60 cut-off point: In the Bank Case this regards the constructs of *Self* (0.557) and *Threat Flexibility* (0.576). In the NPP Case this regards *Self* (0.579). Note also that some items were dropped from the original factor analysis (Appendix H and Appendix I) because of an amelioration of internal consistency.

Note that generally speaking, the internal consistency of the constructs is stronger for the NPP Case (Table 6.2) than for the Bank Case (Table 6.1). In line with theory, this observation gives a first indication that the HRO propensity of the NPP is higher than the HRO propensity of the Bank.

Given the difficulty in developing meaningful assessment devices that are not only based on statistical relevance but that also take theoretical considerations and empirical observations into account, this scale seems to represent a very acceptable and useful assessment (Koch, 1993, p. 87). It is the basis for the analysis described in the remainder of this chapter.

2 Comparing the Bank Case and the NPP Case [RQ1]

Following this validation of the reconceptualized model on construct level, this section answers the first research question underlying this research. To this end, we test the corresponding research propositions and hypotheses. Their analysis is presented in what follows.

Proposition 1-1

Proposition 1-1: HRO properties are not unique, but HRO propensity levels are

H1-1: HRO properties will be discernible in the archetypical HRO (NPP) as well as in the mainstream High Reliability Seeking organization (Bank).

This hypothesis can be validated. From Table 6.1 (for the Bank Case) and Table 6.2 (for the NPP Case) can be seen that an exploratory factor analysis describes constructs with sufficient internal consistency that match the constructs described in HRT literature.

Proposition 1-2

Proposition 1-2: The non-archetypical HRO (the Bank) exhibits the same HRO characteristics as the archetypical HRO (the NPP) but to a lesser extent.

H1-2a: The average HRO propensity at the Bank is lower than at the NPP

This hypothesis can be validated Table 6.3. The standard deviation in the NPP (0,21450) is considerably higher though than in the Bank (0,11385).

HRT	*Min.*	*Max.*	*Mean*	*St.Dev.*
Bank	3,77	4,26	3,9912	,11385
NPP	3,60	4,74	4,1210	21450

Table 6.3 - Comparison HRT propensity (team level)

H1-2b: The average Team Orientation at the Bank is lower than at the NPP

This hypothesis could be validated (Table 6.4).

	Case	*Min.*	*Max.*	*Mean*	*Std. Deviation*
HRT	Bank	3,77	4,26	3,9912	,11385
	NPP	3,60	4,74	4,1210	,21450
Team Orientation	Bank	3,55	4,60	4,1633	,22298
	NPP	3,75	5,00	4,2506	,32341
Preoccupation with Failure	Bank	3,75	4,47	4,1451	,14693
	NPP	3,60	4,90	4,2879	,28058
Deference to Expertise	Bank	3,36	4,20	3,7556	,19547
	NPP	3,47	4,60	3,8375	,25530
Sensitivity to Operations	Bank	3,50	4,40	3,8832	,22418
	NPP	3,67	5,00	4,1704	,32131
SenseMaking	NPP	3,24	4,07	3,6543	,22483
	Bank	3,32	4,05	3,7293	,17447
Other	Bank	3,19	4,25	3,8414	,27070
	NPP	3,44	4,50	4,0374	,33292
Self	Bank	3,00	4,50	3,8453	,30591
	NPP	3,50	4,50	4,1237	,28036
Scheme	Bank	2,78	4,13	3,5025	,27394
	NPP	1,25	3,50	2,5824	,52405
Moderator variables					
Deviation	Bank	2,50	3,60	3,0685	,24605
	NPP	3,00	4,33	3,7222	,38616
Efficiency	Bank	3,00	4,18	3,5978	,33402
	NPP	2,60	3,86	3,2112	,33684
Threat Flexibility	Bank	3,29	4,20	3,6941	,21486
	NPP	3,22	4,50	3,6671	,30368

Table 6.4 - Comparison between cases on team construct level

H1-2c: The average Threat Flexibility at the Bank is lower than at the NPP

This hypothesis could not be validated (Table 6.4), but the difference is only marginal (Bank: 3,6941 vs. NPP: 3,6671).

H1-2d: The average Preoccupation with Failure at the Bank is lower than at the NPP

This hypothesis could be validated (Table 6.4) (Bank: 4,1451 vs. NPP: 4,2879).

H1-2e: The average Sensitivity to Operations at the Bank is lower than at the NPP

This hypothesis could be validated (Table 6.4) (Bank: 3,8832 vs. NPP: 4,1704).

H1-2f: The average Deference to Expertise at the Bank is lower than at the NPP

This hypothesis could be validated (Table 6.4) (Bank: 3,7556 vs. NPP: 3,8375)

Proposition 1-3

Proposition 1-3: The higher the requisite variety of a team, the higher its HRO propensity

H1-3a: Teams using richer media exhibit a higher HRO propensity.

For the Bank Case, this hypothesis can be validated at an acceptable level of significance (0.034) (Table 6.6) where teams that rely more on face-to-face communication exhibit a higher HRO propensity (3,9530 vs. 4,0315) (Table 6.5). Drilling down to the level of the HRT sub-constructs, we see that especially Deference to Expertise (p = 0.031 with means: 3,6889 vs. 3,8261) and Sensitivity to Operations (p = 0,008) with means: 3,7906 vs. 3,9809) are accountable for this observation.

		N	*Mean*	*Std. Deviation*	*Std. Error*	*95% Confidence Interval for Mean*		*Min.*	*Max.*
						Lower Bound	*Upper Bound*		
Team Orientation	L	19	4,1275	,21358	,04900	4,0246	4,2305	3,55	4,53
	H	18	4,2011	,23248	,05480	4,0855	4,3167	3,80	4,60
	Total	37	4,1633	,22298	,03666	4,0890	4,2376	3,55	4,60
Preoccupation with Failure	L	19	4,1605	,14445	,03314	4,0909	4,2302	3,87	4,47
	H	18	4,1287	,15189	,03580	4,0532	4,2042	3,75	4,40
	Total	37	4,1451	,14693	,02415	4,0961	4,1940	3,75	4,47
Deference to Expertise	L	19	3,6889	,18149	,04164	3,6014	3,7764	3,36	4,06
	H	18	3,8261	,18919	,04459	3,7320	3,9202	3,50	4,20
	Total	37	3,7556	,19547	,03213	3,6905	3,8208	3,36	4,20
SO	L	19	3,7906	,18226	,04181	3,7028	3,8785	3,50	4,10

	H	18	3,9809	,22711	,05353	3,8679	4,0938	3,63	4,40
	Total	37	3,8832	,22418	,03686	3,8084	3,9579	3,50	4,40
SeMa	L	19	3,7499	,17364	,03984	3,6662	3,8336	3,32	3,96
	H	18	3,7075	,17765	,04187	3,6191	3,7958	3,37	4,05
	Total	37	3,7293	,17447	,02868	3,6711	3,7874	3,32	4,05
Other	L	19	3,8855	,22635	,05193	3,7764	3,9946	3,19	4,25
	H	18	3,7948	,31056	,07320	3,6403	3,9492	3,20	4,25
	Total	37	3,8414	,27070	,04450	3,7511	3,9316	3,19	4,25
Self	L	19	3,9422	,26196	,06010	3,8160	4,0685	3,50	4,50
	H	18	3,7429	,32234	,07598	3,5826	3,9032	3,00	4,13
	Total	37	3,8453	,30591	,05029	3,7433	3,9473	3,00	4,50
Scheme	L	19	3,4409	,27764	,06369	3,3071	3,5747	2,78	3,92
	H	18	3,5675	,26188	,06173	3,4373	3,6977	3,06	4,13
	Total	37	3,5025	,27394	,04504	3,4111	3,5938	2,78	4,13
Threat Flexibility	L	19	3,6543	,20314	,04660	3,5564	3,7522	3,29	4,08
	H	18	3,7362	,22457	,05293	3,6245	3,8478	3,38	4,20
	Total	37	3,6941	,21486	,03532	3,6225	3,7658	3,29	4,20
Efficiency	L	19	3,5230	,26889	,06169	3,3934	3,6526	3,00	4,08
	H	18	3,6766	,38324	,09033	3,4861	3,8672	3,06	4,18
	Total	37	3,5978	,33402	,05491	3,4864	3,7091	3,00	4,18
Logics of Action	L	19	3,8116	,21911	,05027	3,7060	3,9172	3,33	4,22
	H	18	3,8181	,26344	,06209	3,6871	3,9491	3,25	4,44
	Total	37	3,8147	,23830	,03918	3,7353	3,8942	3,25	4,44
Deviation	L	19	2,9814	,26027	,05971	2,8560	3,1069	2,50	3,40
	H	18	3,1603	,19767	,04659	3,0620	3,2586	2,92	3,60
	Total	37	3,0685	,24605	,04045	2,9864	3,1505	2,50	3,60
HRT	L	19	3,9530	,08256	,01894	3,9133	3,9928	3,78	4,15
	H	18	4,0315	,12993	,03062	3,9669	4,0961	3,77	4,26
	Total	37	3,9912	,11385	,01872	3,9533	4,0292	3,77	4,26

Table 6.5 - ANOVA Descriptives for Face-to-face Communication (Bank)

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Team Orientation	Between Groups	,050	1	,050	1,006	,323
	Within Groups	1,740	35	,050		
	Total	1,790	36			
Preoccupation with Failure	Between Groups	,009	1	,009	,427	,518
	Within Groups	,768	35	,022		
	Total	,777	36			
Deference to Expertise	Between Groups	,174	1	,174	5,071	,031
	Within Groups	1,201	35	,034		
	Total	1,375	36			
SO	Between Groups	,335	1	,335	7,939	,008
	Within Groups	1,475	35	,042		
	Total	1,809	36			
SeMa	Between Groups	,017	1	,017	,540	,467
	Within Groups	1,079	35	,031		
	Total	1,096	36			
Other	Between Groups	,076	1	,076	1,040	,315
	Within Groups	2,562	35	,073		
	Total	2,638	36			
Self	Between Groups	,367	1	,367	4,283	,046
	Within Groups	3,002	35	,086		
	Total	3,369	36			
Scheme	Between Groups	,148	1	,148	2,031	,163
	Within Groups	2,553	35	,073		
	Total	2,702	36			
Threat Flexibility	Between Groups	,062	1	,062	1,354	,252
	Within Groups	1,600	35	,046		
	Total	1,662	36			
Efficiency	Between Groups	,218	1	,218	2,010	,165

	Within Groups	3,798	35	,109		
	Total	4,016	36			
Logics of Action	Between Groups	,000	1	,000	,007	,935
	Within Groups	2,044	35	,058		
	Total	2,044	36			
Deviation	Between Groups	,296	1	,296	5,497	,025
	Within Groups	1,884	35	,054		
	Total	2,179	36			
HRT	Between Groups	,057	1	,057	4,863	,034
	Within Groups	,410	35	,012		
	Total	,467	36			

Table 6.6 - ANOVA for Face-to-face Communication (Bank)

For the NPP Case, this hypothesis can be validated at an acceptable level of significance (0.031) (Table 6.16) for the NPP Case where teams that rely more on face-to-face communication exhibit a higher HRO propensity (4,0283 vs. 4,2136). Drilling down to the level of the HRT sub-constructs, we see that especially Team Orientation (p = 0.012 with means: 4,0909 vs. 4,4104) and Sensitivity to Operations (p = 0.061 with means: 4,0485 vs. 4,2924) are accountable for this observation.

H1-3b: More experienced teams exhibit a higher HRO propensity.

This hypothesis cannot be validated at an acceptable level of significance (Table 6.7).

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Team Orientation	Between Groups	,000	1	,000	,002	,968
	Within Groups	2,406	22	,109		
	Total	2,406	23			
Sensitivity to Operations	Between Groups	,071	1	,071	,680	,419
	Within Groups	2,303	22	,105		
	Total	2,375	23			
Preoccupation with Failure	Between Groups	,001	1	,001	,016	,900
	Within Groups	1,809	22	,082		
	Total	1,811	23			

Deference to Expertise	Between Groups	,000	1	,000	,000	1,000
	Within Groups	1,499	22	,068		
	Total	1,499	23			
HRT	Between Groups	,004	1	,004	,076	,785
	Within Groups	1,055	22	,048		
	Total	1,058	23			
Other	Between Groups	,020	1	,020	,173	,681
	Within Groups	2,529	22	,115		
	Total	2,549	23			
Self	Between Groups	,009	1	,009	,110	,743
	Within Groups	1,799	22	,082		
	Total	1,808	23			
Scheme	Between Groups	,295	1	,295	1,079	,310
	Within Groups	6,021	22	,274		
	Total	6,317	23			
SeMa	Between Groups	,001	1	,001	,010	,923
	Within Groups	1,162	22	,053		
	Total	1,163	23			
Threat Flexibility	Between Groups	,024	1	,024	,250	,622
	Within Groups	2,097	22	,095		
	Total	2,121	23			
Efficiency	Between Groups	,224	1	,224	2,066	,165
	Within Groups	2,386	22	,108		
	Total	2,610	23			
Pressure	Between Groups	,109	1	,109	1,163	,292
	Within Groups	2,061	22	,094		
	Total	2,170	23			
SupRes	Between Groups	,120	1	,120	1,185	,288
	Within Groups	2,231	22	,101		

	Total	2,352	23			
Deviation	Between Groups	,111	1	,111	,736	,400
	Within Groups	3,319	22	,151		
	Total	3,430	23			

Table 6.7 - ANOVA for Experience (NPP)

Proposition 1-4

***Propostion 1-4*:** The higher the requisite variety of a team, the higher its SeMa propensity

H1-4a: Teams using richer media will exhibit a higher SeMa propensity.

H1-4b: More experienced teams exhibit a higher SeMa propensity.

In the Bank Case, we found no proof for this assertion at an acceptable significance for the SeMa root construct, but when drilling down to the level of the sub-constructs, at a significance of 0.032 (Table 6.8), a falsification for the hypothesis could be provided. Table 6.9 shows that teams a lower score on Scheme, are more experienced on average than teams exhibiting a higher score on Scheme (8,8755 vs. 6,0127). In the NPP Case, no acceptable level of significance allowed for a reliable interpretation, or regarding the SeMa root, nor the SeMa sub-constructs.

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Between Groups	75,753	1	75,753	5,014	,032
Within Groups	528,742	35	15,107		
Total	604,495	36			

Table 6.8 - ANOVA for Experience vs. SeMa Scheme (Bank)

	N	*Mean*	*Std. Deviation*	*Std. Error*	*95% Confidence Interval for Mean*		*Minimum*	Maximum
					Lower Bound	Upper Bound		
L	19	8,8755	4,90581	1,12547	6,5109	11,2400	3,00	23,33
H	18	6,0127	2,37061	,55876	4,8338	7,1916	3,41	11,33
Total	37	7,4828	4,09775	,67367	6,1165	8,8490	3,00	23,33

Table 6.9 - ANOVA Descriptive Statistics for Experience vs. SeMa Scheme (Bank)

Proposition 1-5

Proposition 1-5: The non-archetypical HRO (the Bank) exhibits the same HRO characteristics as the archetypical HRO (the NPP) but exhibits a lower variance.

	Case	*Min.*	*Max.*	*Mean*	*Std. Deviation*
HRT	Bank	3,77	4,26	3,9912	,11385
	NPP	3,60	4,74	4,1210	,21450
Team Orientation	Bank	3,55	4,60	4,1633	,22298
	NPP	3,75	5,00	4,2506	,32341
Efficiency	Bank	3,00	4,18	3,5978	,33402
	NPP	2,60	3,86	3,2112	,33684
Threat Flexibility	Bank	3,29	4,20	3,6941	,21486
	NPP	3,22	4,50	3,6671	,30368
Preoccupation with Failure	Bank	3,75	4,47	4,1451	,14693
	NPP	3,60	4,90	4,2879	,28058
Deference to Expertise	Bank	3,36	4,20	3,7556	,19547
	NPP	3,47	4,60	3,8375	,25530
Sensitivity to Operations	Bank	3,50	4,40	3,8832	,22418
	NPP	3,67	5,00	4,1704	,32131
SenseMaking	NPP	3,24	4,07	3,6543	,22483
	Bank	3,32	4,05	3,7293	,17447
Other	Bank	3,19	4,25	3,8414	,27070
	NPP	3,44	4,50	4,0374	,33292
Self	Bank	3,00	4,50	3,8453	,30591
	NPP	3,50	4,50	4,1237	,28036
Scheme	Bank	2,78	4,13	3,5025	,27394
	NPP	1,25	3,50	2,5824	,52405
Moderator variables					
Deviation	Bank	2,50	3,60	3,0685	,24605
	NPP	3,00	4,33	3,7222	,38616

Table 6.10 - HRO Construct Comparison

Taking the standard deviation as a measure of this variance (spread), we come to the following findings:

H1-5a: The variance in HRO propensity at the Bank is lower than at the NPP

This hypothesis is validated (0,11385 vs. 0,21450)

H1-5b: The variance in Team Orientation at the Bank is lower than at the NPP

This hypothesis is validated (0,22298 vs. 0,32341)

H1-5c: The variance in Threat Flexibility at the Bank is lower than at the NPP

This hypothesis is validated (0,21486 vs. 0,30368)

H1-5d: The variance in Preoccupation with Failure at the Bank is lower than at the NPP

This hypothesis is validated (0,14693 vs. 0,28058)

H1-1-5e: The variance in Sensitivity to Operations at the Bank is lower than at the NPP

This hypothesis is validated (0,22418 vs. 0,32131)

H1-5f: The variance in Deference to Expertise at the Bank is lower than at the NPP

This hypothesis is validated (0,19547 vs. 0,25530)

Proposition 1-6

Proposition 1-6: The non-archetypical HRO (the Bank) exhibits the same SeMa characteristics as the archetypical HRO (the NPP) but exhibits a lower variance.

H1-6a: The variance in SenseMaking propensity at the Bank is lower than at the NPP

This hypothesis is falsified (0,22483 vs. 0,17447)

At the level of the root SeMa construct, this hypothesis is falsified. However, two out of three of its underlying sub-constructs can be validated.

H1-6b: The variance in Self propensity at the Bank is lower than at the NPP

This hypothesis is falsified (0,30591 vs. 0,28036)

H1-6c: The variance in Other propensity at the Bank is lower than at the NPP

This hypothesis is validated (0,27070 vs. 0,33292)

H1-6d: The variance in Scheme propensity at the Bank is lower than at the NPP

This hypothesis is validated (0,27394 vs. 0,52405)

Proposition 1-7

Proposition 1-7: The constructs of Mindfulness and Resilience interrelate

Another presumption seems to be that the different constituting HRO factors are independent from each other in the sense that they do not conflict. Being preoccupied with failure in combination with being reluctant to simplify poses no problem. This is in conflict with what has been suggested by NAT, namely that since HROs operate in a setting of complexity and tight-coupling, it is cognitively impossible to "*predict everything and set up systems that alert them to* *small changes so that they can prevent these small changes from becoming big problems*"(Longstaff, 2003, p. 19).

H1-7a: The higher a team's Preoccupation with Failure, the lower its Deference to Expertise.

We have not been able to validate this hypothesis in the Bank Case at an acceptable level of significance (Table 6.13). In the NPP Case, we see that at an acceptable significance (p 0.029) (Table 6.14) the hypothesis could be falsified. A low degree of Deference to Expertise matches a low degree of Preoccupation with Failure and vice versa (4,1652 vs. 4,4105).

H1-7b: Being mindful is a prerequisite for being resilient.

We have been able to validate this hypothesis (p 0.047) (See: Table 6.11) for the Bank Case as teams with a low degree of Deference to Expertise exhibit a low score on Sensitivity to Operations (3,8123 vs. 3,9580) (Table 6.12). It has been impossible to validate the hypothesis for the NPP Case at an acceptable level of significance (Table 6.14).

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Team Orientation	Between Groups	,034	1	,034	,675	,417
	Within Groups	1,756	35	,050		
	Total	1,790	36			
Preoccupation with Failure	Between Groups	,000	1	,000	,015	,902
	Within Groups	,777	35	,022		
	Total	,777	36			
Deference to Expertise	Between Groups	,746	1	,746	41,470	,000
	Within Groups	,630	35	,018		
	Total	1,375	36			
SO	Between Groups	,196	1	,196	4,256	,047
	Within Groups	1,613	35	,046		
	Total	1,809	36			
SeMa	Between Groups	,104	1	,104	3,655	,064
	Within Groups	,992	35	,028		
	Total	1,096	36			
Other	Between Groups	,093	1	,093	1,278	,266
	Within Groups	2,545	35	,073		
	Total	2,638	36			

Self	Between Groups	,003	1	,003	,033	,857
	Within Groups	3,366	35	,096		
	Total	3,369	36			
Scheme	Between Groups	,272	1	,272	3,920	,056
	Within Groups	2,429	35	,069		
	Total	2,702	36			
Threat Flexibility	Between Groups	,306	1	,306	7,895	,008
	Within Groups	1,356	35	,039		
	Total	1,662	36			
Efficiency	Between Groups	,736	1	,736	7,854	,008
	Within Groups	3,280	35	,094		
	Total	4,016	36			
Logics of Action	Between Groups	,081	1	,081	1,437	,239
	Within Groups	1,964	35	,056		
	Total	2,044	36			
Deviation	Between Groups	,000	1	,000	,000	,986
	Within Groups	2,179	35	,062		
	Total	2,179	36			
HRT	Between Groups	,155	1	,155	17,369	,000
	Within Groups	,312	35	,009		
	Total	,467	36			

Table 6.11 - ANOVA for Deference to expertise (Bank)

		N	Mean	Std. Dev.	Std. Error	95% Confidence Interval for Mean		Min.	Max.
						Lower Bound	Upper Bound		
Team Orientation	L	19	4,1338	,22123	,05075	4,0272	4,2405	3,55	4,53
	H	18	4,1944	,22688	,05348	4,0816	4,3072	3,80	4,60
	Total	37	4,1633	,22298	,03666	4,0890	4,2376	3,55	4,60
Preoccupation with Failure	L	19	4,1421	,16223	,03722	4,0639	4,2203	3,75	4,47
	H	18	4,1482	,13352	,03147	4,0818	4,2146	3,87	4,40
	Total	37	4,1451	,14693	,02415	4,0961	4,1940	3,75	4,47
Deference to Expertise	L	19	3,6174	,13083	,03001	3,5544	3,6805	3,36	3,75
	H	18	3,9015	,13750	,03241	3,8331	3,9699	3,76	4,20
	Total	37	3,7556	,19547	,03213	3,6905	3,8208	3,36	4,20
SO	L	19	3,8123	,19367	,04443	3,7190	3,9057	3,60	4,29
	H	18	3,9580	,23490	,05537	3,8412	4,0748	3,50	4,40
	Total	37	3,8832	,22418	,03686	3,8084	3,9579	3,50	4,40
SeMa	L	19	3,6778	,17752	,04073	3,5922	3,7633	3,32	3,93
	H	18	3,7836	,15811	,03727	3,7050	3,8623	3,47	4,05
	Total	37	3,7293	,17447	,02868	3,6711	3,7874	3,32	4,05
Other	L	19	3,7926	,30261	,06942	3,6467	3,9385	3,19	4,25
	H	18	3,8929	,22967	,05413	3,7786	4,0071	3,36	4,25
	Total	37	3,8414	,27070	,04450	3,7511	3,9316	3,19	4,25
Self	L	19	3,8362	,26877	,06166	3,7067	3,9658	3,33	4,17
	H	18	3,8548	,34856	,08216	3,6815	4,0281	3,00	4,50
	Total	37	3,8453	,30591	,05029	3,7433	3,9473	3,00	4,50
Scheme	L	19	3,4190	,27388	,06283	3,2870	3,5510	2,78	3,74
	H	18	3,5906	,25196	,05939	3,4653	3,7159	3,03	4,13
	Total	37	3,5025	,27394	,04504	3,4111	3,5938	2,78	4,13
Threat Flexibility	L	19	3,6056	,16531	,03792	3,5260	3,6853	3,29	3,88

	H	18	3,7876	,22547	,05314	3,6754	3,8997	3,35	4,20
	Total	37	3,6941	,21486	,03532	3,6225	3,7658	3,29	4,20
Efficiency	L	19	3,4605	,29690	,06811	3,3174	3,6036	3,00	4,11
	H	18	3,7427	,31564	,07440	3,5857	3,8996	3,10	4,18
	Total	37	3,5978	,33402	,05491	3,4864	3,7091	3,00	4,18
Logics of Action	L	19	3,7693	,21399	,04909	3,6662	3,8725	3,25	4,22
	H	18	3,8627	,25890	,06102	3,7340	3,9915	3,33	4,44
	Total	37	3,8147	,23830	,03918	3,7353	3,8942	3,25	4,44
Deviation	L	19	3,0677	,24524	,05626	2,9495	3,1859	2,67	3,40
	H	18	3,0692	,25401	,05987	2,9429	3,1955	2,50	3,60
	Total	37	3,0685	,24605	,04045	2,9864	3,1505	2,50	3,60
HRT	L	19	3,9283	,08186	,01878	3,8888	3,9677	3,77	4,10
	H	18	4,0577	,10605	,02500	4,0049	4,1104	3,88	4,26
	Total	37	3,9912	,11385	,01872	3,9533	4,0292	3,77	4,26

Table 6.12 - Descriptives for ANOVA for Deference to Expertise (Bank)

We have been able to validate this hypothesis (p 0.029) (See: Table 6.14) for the NPP Case as teams with a lower Deference to Expertise exhibit a lower degree of Preoccupation with Failure (4,1652 vs. 4,4105).

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Team Orientation	Between Groups	,053	1	,053	1,059	,310
	Within Groups	1,737	35	,050		
	Total	1,790	36			
Deference to Expertise	Between Groups	,007	1	,007	,170	,683
	Within Groups	1,369	35	,039		
	Total	1,375	36			
Sensitivity to Operations	Between Groups	,013	1	,013	,259	,614
	Within Groups	1,796	35	,051		

Table 6.13 - ANOVA for Preoccupaton with failure vs. Deference to Expertise (Bank)

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Threat Flexibility	Between Groups	,872	1	,872	15,347	,001
	Within Groups	1,249	22	,057		
	Total	2,121	23			
Efficiency	Between Groups	,510	1	,510	5,341	,031
	Within Groups	2,100	22	,095		
	Total	2,610	23			
Pressure	Between Groups	,257	1	,257	2,954	,100
	Within Groups	1,913	22	,087		
	Total	2,170	23			
SupRes	Between Groups	,269	1	,269	2,842	,106
	Within Groups	2,083	22	,095		
	Total	2,352	23			
Deviation	Between Groups	,204	1	,204	1,392	,251
	Within Groups	3,226	22	,147		
	Total	3,430	23			
Team Orientation	Between Groups	,051	1	,051	,480	,495
	Within Groups	2,354	22	,107		
	Total	2,406	23			
SO	Between Groups	,090	1	,090	,871	,361
	Within Groups	2,284	22	,104		
	Total	2,375	23			
Preoccupation with Failure	Between Groups	,361	1	,361	5,478	,029
	Within Groups	1,450	22	,066		
	Total	1,811	23			
Deference to Expertise	Between Groups	,766	1	,766	22,982	,000
	Within Groups	,733	22	,033		
	Total	1,499	23			
HRT	Between Groups	,309	1	,309	9,054	,006

	Within Groups	,750	22	,034		
	Total	1,058	23			
Other	Between Groups	,039	1	,039	,344	,564
	Within Groups	2,510	22	,114		
	Total	2,549	23			
Self	Between Groups	,215	1	,215	2,962	,099
	Within Groups	1,593	22	,072		
	Total	1,808	23			
Scheme	Between Groups	,245	1	,245	,889	,356
	Within Groups	6,071	22	,276		
	Total	6,317	23			
SeMa	Between Groups	,017	1	,017	,324	,575
	Within Groups	1,146	22	,052		
	Total	1,163	23			

Table 6.14 - ANOVA for Deference to Expertise vs. Preoccupation with failure (NPP)

		N	*Mean*	*Std. Dev.*	*Std. Error*	*95% Confidence Interval for Mean* Lower Bound	Upper Bound	*Min.*	*Max.*
Threat Flexibility	L	12	3,4765	,18616	,05374	3,3582	3,5948	3,22	3,72
	H	12	3,8577	,28095	,08110	3,6792	4,0362	3,44	4,50
	Total	24	3,6671	,30368	,06199	3,5389	3,7953	3,22	4,50
Efficiency	L	12	3,3569	,29291	,08456	3,1708	3,5431	2,67	3,86
	H	12	3,0655	,32419	,09359	2,8595	3,2715	2,60	3,50
	Total	24	3,2112	,33684	,06876	3,0690	3,3534	2,60	3,86
Pressure	L	12	3,2778	,26924	,07772	3,1067	3,4488	2,78	3,76
	H	12	3,0709	,31847	,09193	2,8685	3,2732	2,60	3,56
	Total	24	3,1743	,30715	,06270	3,0446	3,3040	2,60	3,76
SupRes	L	12	3,3701	,32037	,09248	3,1666	3,5737	2,76	3,75
	H	12	3,5819	,29443	,08500	3,3948	3,7689	3,03	4,00
	Total	24	3,4760	,31976	,06527	3,3410	3,6110	2,76	4,00

Deviation	L	12	3,6300	,38759	,11189	3,3837	3,8762	3,00	4,29
	H	12	3,8144	,37818	,10917	3,5741	4,0547	3,00	4,33
	Total	24	3,7222	,38616	,07883	3,5591	3,8852	3,00	4,33
Team Orientation	L	12	4,2044	,32415	,09358	3,9984	4,4103	3,75	5,00
	H	12	4,2969	,33008	,09529	4,0872	4,5067	3,75	4,88
	Total	24	4,2506	,32341	,06602	4,1141	4,3872	3,75	5,00
SO	L	12	4,1090	,35375	,10212	3,8843	4,3338	3,67	5,00
	H	12	4,2318	,28725	,08292	4,0493	4,4143	3,75	4,75
	Total	24	4,1704	,32131	,06559	4,0347	4,3061	3,67	5,00
Preoccupation with Failure	L	12	4,1652	,29134	,08410	3,9801	4,3503	3,60	4,64
	H	12	4,4105	,21657	,06252	4,2729	4,5481	4,12	4,90
	Total	24	4,2879	,28058	,05727	4,1694	4,4064	3,60	4,90
Deference to Expertise	L	12	3,6588	,14137	,04081	3,5690	3,7487	3,47	3,80
	H	12	4,0161	,21603	,06236	3,8789	4,1534	3,81	4,60
	Total	24	3,8375	,25530	,05211	3,7297	3,9453	3,47	4,60
HRT	L	12	4,0076	,16234	,04686	3,9044	4,1107	3,60	4,22
	H	12	4,2344	,20446	,05902	4,1044	4,3643	3,95	4,74
	Total	24	4,1210	,21450	,04379	4,0304	4,2115	3,60	4,74
Other	L	12	3,9970	,31468	,09084	3,7970	4,1969	3,53	4,50
	H	12	4,0778	,35939	,10375	3,8495	4,3061	3,44	4,50
	Total	24	4,0374	,33292	,06796	3,8968	4,1780	3,44	4,50
Self	L	12	4,2183	,24329	,07023	4,0637	4,3728	3,75	4,50
	H	12	4,0292	,29268	,08449	3,8432	4,2151	3,50	4,50
	Total	24	4,1237	,28036	,05723	4,0053	4,2421	3,50	4,50
Scheme	L	12	2,4813	,43703	,12616	2,2037	2,7590	2,00	3,30
	H	12	2,6835	,60078	,17343	2,3018	3,0652	1,25	3,50
	Total	24	2,5824	,52405	,10697	2,3611	2,8037	1,25	3,50
SeMa	L	12	3,6277	,18777	,05421	3,5084	3,7470	3,33	3,86
	H	12	3,6808	,26249	,07577	3,5140	3,8476	3,24	4,07
	Total	24	3,6543	,22483	,04589	3,5593	3,7492	3,24	4,07

Table 6.15 - Descriptives for ANOVA for Deference to Expertise vs. Preoccupation with failure (NPP)

Proposition 1-8

Proposition 1-8: The NPP is more reliable than the Bank

H1-8: The NPP is more reliable than the Bank

It would be relevant if we were able to compare organizational reliability between cases. Unfortunately, it is not achievable to compare the reliability of both organizations as the processes under study – however similar – are not identical[69]. What we can compare however is the range in of standardized reliability (*ZScore*). This range is a proxy of reliability as it corresponds to availability of the incident management/maintenance process as a service. An overview of this range is provided in Appendix J as Table 0.34, for the reliability of the Bank's Incident Management process and in Table 0.35, for the reliability of the NPP's Maintenance & Repair process. The conclusion is that the range at the Bank is 3,72076; 5,03739 and 4,39108 for the handling of urgent, non-urgent and all incidents respectively. For the NPP the corresponding ranges are 4,88034; 4,64523 and 4,86319. The conclusion therefore is that – based on this criterion for inter-case comparison of process reliability – the Bank is more reliable than the NPP with respect to the urgent incidents, less reliable than the NPP in the handling of non-urgent incidents and again more reliable than the NPP regarding the overall handling of incidents.

		Sum of Squares	*df*	*Mean Square*	*F*	*Sig.*
Team Orientation	Between Groups	,613	1	,613	7,516	,012
	Within Groups	1,793	22	,082		
	Total	2,406	23			
SO	Between Groups	,357	1	,357	3,891	,061
	Within Groups	2,018	22	,092		
	Total	2,375	23			
Preoccupation with Failure	Between Groups	,123	1	,123	1,609	,218
	Within Groups	1,687	22	,077		
	Total	1,811	23			
Deference to Expertise	Between Groups	,064	1	,064	,982	,332
	Within Groups	1,435	22	,065		
	Total	1,499	23			
HRT	Between Groups	,206	1	,206	5,317	,031
	Within Groups	,852	22	,039		
	Total	1,058	23			

Other	Between Groups	,582	1	,582	6,503	,018
	Within Groups	1,968	22	,089		
	Total	2,549	23			
Self	Between Groups	,006	1	,006	,067	,797
	Within Groups	1,802	22	,082		
	Total	1,808	23			
Scheme	Between Groups	,002	1	,002	,008	,931
	Within Groups	6,314	22	,287		
	Total	6,317	23			
SeMa	Between Groups	,081	1	,081	1,637	,214
	Within Groups	1,082	22	,049		
	Total	1,163	23			
Threat Flexibility	Between Groups	,375	1	,375	4,728	,041
	Within Groups	1,746	22	,079		
	Total	2,121	23			
Efficiency	Between Groups	,114	1	,114	1,003	,328
	Within Groups	2,496	22	,113		
	Total	2,610	23			
Pressure	Between Groups	,181	1	,181	2,001	,171
	Within Groups	1,989	22	,090		
	Total	2,170	23			
SupRes	Between Groups	,692	1	,692	9,180	,006
	Within Groups	1,659	22	,075		
	Total	2,352	23			
Deviation	Between Groups	,510	1	,510	3,844	,063
	Within Groups	2,920	22	,133		
	Total	3,430	23			

Table 6.16 - ANOVA for Face-to-face Communication (NPP)

3 Measuring Reliability [RQ2]

An overview of the team scores on each construct and item is provided in Appendix D for the Bank Case and in Appendix E for the NPP Case.The codes used in the analysis in this section have the following logic. D: Dichotomized Variable; M: Mean value; S: Standard deviation, followed by the abbreviated variable name. For instance, TO for Team Orientation) (Table 6.17). The code composition for the dichotomized mean of the Team Orientation variable, therefore is DMTO, its dichotomized standard deviation DSTO.

DE	Deference to Expertise
LA	Logics of Action
Dev	Deviation
Ef	Efficiency
NU12pe	Average number of urgent incidents per employee
NU3pe	Average number of non-urgent incidents per employee
NUApe	Average number of incidents per employee
Other	SenseMaking Other
HRT	Overall High Reliability propensity
PF	Preoccupation with Failure
Pres	Pressure
Scheme	SenseMaking Scheme
Self	SenseMaking Self
SeMa	Overall SenseMaking propensity
SO	Sensitivity to Operations
TO	Team Orientation
TF	Threat Flexibility
TS	Team Size

Table 6.17 - Construct Abbreviations

3.1 Bank Case

In this section, we examine what makes one team more reliable, more performant than another team. Which contextual and/or structural dimensions contribute to high reliability? In addition, how do these dimensions (or constructs) interrelate? Can a non-archetypical HRO and archetypical HRO learn from each other? With this second research question, we analyze the interrelationships that exist between the different determinants and wish to come to an integrating framework that has the potential of contributing to the explanation of reliability. The data provided in this section show only those analyses that have a sufficient statistical significance. The analyses with a statistical significance that is too low for our purposes (See: Chapter 3, Section 6) are omitted from the description.

Proposition 2-1

H2-1a: Teams exhibiting a higher propensity towards Team Orientation yield higher reliability in the handling of urgent incidents, whereas this is counterproductive for the handling of non-urgent incidents.

No evidence has been found for this hypothesis ($p \leq 0.10$).

H2-1b: Teams exhibiting a high propensity towards Team Orientation and exhibiting a high degree of Sensitivity to Operations yield a higher reliability than teams than the same teams exhibiting a low degree of Sensitivity to Operations.

We have found no evidence for this hypothesis at p≤0.10.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Max*	*Min*	*Spread*
Bank	PU12	DMTO	DM137	0,04	0,57	0,68	0,75	0,47	0,75	0,47	0,28
Bank	PU3	DMTO	DM137	0,08	0,90	0,96	0,98	0,88	0,98	0,88	0,11
Bank	PU3	DMTO	DMDE	0,11	0,94	0,89	0,87	0,97	0,97	0,87	0,10

Table 6.18 - Two-way ANOVA for Team Orientation

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Max*	*Min*	*Spread*
Bank	PU12	DSTO	DM137	0,01	0,76	0,43	0,53	0,64	0,76	0,43	0,33
Bank	PU12	DSTO	DM10	0,05	0,78	0,47	0,56	0,59	0,78	0,47	0,31
Bank	PU12	DSTO	DS10	0,06	0,50	0,80	0,59	0,56	0,80	0,50	0,30
Bank	PU12	DSTO	DSDE	0,04	0,57	0,68	0,73	0,47	0,73	0,47	0,25
Bank	PU3	DSTO	DSDE	0,06	0,90	0,98	0,96	0,87	0,98	0,87	0,11
Bank	PU3	DSTO	DM137	0,10	0,98	0,87	0,90	0,94	0,98	0,87	0,11

Table 6.19 - Two-way ANOVA for Spread of Team Orientation

H2-1c: The higher the average Threat Flexibility, the higher the reliability.

Falsification of this hypothesis: For urgent incidents, a low average score on Threat Flexibility results in the highest reliability (0.67 at p≤0.05).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Max*	*Min*	*Spread*
Bank	PU12	DMTF	DMNU12pe	0,10	0,59	0,70	0,30	0,65	0,70	0,30	0,40
Bank	PU12	DMTF	DMEff	0,03	0,64	0,70	0,32	0,68	0,70	0,32	0,39
Bank	PU12	DMTF	DM1	0,02	0,61	0,70	0,64	0,36	0,70	0,36	0,34
Bank	PU3	DMTF	DM1	0,04	0,96	0,95	0,96	0,78	0,96	0,78	0,18
Bank	PU3	DMTF	DMPF	0,06	0,94	0,96	0,94	0,79	0,96	0,79	0,17
Bank	PU3	DMTF	DMNU12pe	0,08	0,97	0,94	0,83	0,96	0,97	0,83	0,14
Bank	PU12	DMTF		0,05	0,67	0,50			0,67	0,50	0,17

Table 6.20 - Two-way ANOVA for Threat Flexibility

H2-1d: Teams that operate in a less restrictive (more supportive) organizational climate perform better than teams that do not (Smith-Crowe, Burke, & Landis 2003).

The construct covering the degree of supportiveness is Threat Flexibility.

We have found evidence (p≤0.05) for the falsification of this hypothesis, namely that where the handling of urgent incidents (threat) is concerned, a more restrictive (less supportive) degree of Threat Flexibility, is positively influencing reliability, regardless of any mediating variable. The one-way ANOVA is shown in Table 6.21. We notice however that the spread between the highest and lowest expected average reliability is a little lower (0.17) than the average spread (0.22) (based on the p≤0.10 significance level).

Case	*Type*	*Fact1*	*Sig.*	*LL*	*LH*	*Spread*
Bank	PU12	DMTF	0,05	0,67	0,50	0,17

Table 6.21 - One-way ANOVA for Threat Flexibility

At this one-way ANOVA level, we have found no sufficient significance for non-urgent incidents.

H2-1e: Teams that operate in a less efficiency-driven (more slack) organizational climate perform better than teams that do not.

The construct covering the degree of supportiveness is Efficiency. We have found evidence (p≤0.05) for the falsification of this hypothesis, as well concerning the handling of urgent incidents as the non-urgent incidents. A higher focus on efficiency is positively influencing reliability, regardless of any mediating variable. The one-way ANOVA is shown in Table 6.22. We notice however that the spread between the highest and lowest expected average reliability is a little lower (0.19) than the average spread (0.22) (based on the p≤0.10 significance level) but substantially lower (0.10) for the non-urgent incidents.

Case	*Type*	*Fact1*	*Sig.*	*LL*	*LH*	*Max*	*Min*	*Spread*
Bank	PU12	DMEff	0,02	0,50	0,69	0,69	0,50	0,19
Bank	PU3	DMEff	0,03	0,88	0,97	0,97	0,88	0,10

Table 6.22 - One-way ANOVA for Efficiency

Proposition 2-2

H2-2a: The higher the variance in SeMa propensity, the higher the reliability

We have found no significance to support this hypothesis at the one-way ANOVA level, but at the two-way ANOVA level a low spread in SenseMaking yields the highest reliability (Table 6.23).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DSSeMa	DS2	0,02	0,76	0,50	0,47	0,59	0,30
Bank	Urgent	DSSeMa	DM2	0,05	0,76	0,54	0,47	0,59	0,29
Bank	Urgent	DSSeMa	DS6	0,05	0,76	0,54	0,47	0,59	0,29
Bank	Non-Urgent	DSSeMa	DS4	0,01	0,95	0,98	0,97	0,77	0,21
Bank	Non-Urgent	DSSeMa	DMEff	0,09	0,94	0,97	0,79	0,97	0,18
Bank	Non-Urgent	DSSeMa	DMNU3pe	0,10	0,94	0,97	0,80	0,97	0,17

Bank	Non-Urgent	DSSeMa	DS1	0,08	0,96	0,95	0,97	0,81	0,16
Bank	Non-Urgent	DSSeMa	DMNU12pe	0,08	0,98	0,94	0,84	0,96	0,14
Bank	Non-Urgent	DSSeMa	DS114	0,10	0,97	0,94	0,84	0,96	0,13

Table 6.23 - Two-way ANOVA Analysis for Spread in SenseMaking Propensity

H2-2b: The higher the variance in Scheme, the higher the reliability

We have found no significance to support this hypothesis at the one-way ANOVA level, but at the two-way ANOVA level, a low spread in SenseMaking propensity yields the highest reliability (Table 6.24).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DSScheme	DMNU12pe	0,00	0,59	0,62	0,29	0,77	0,48
Bank	Urgent	DSScheme	DS4	0,07	0,60	0,67	0,71	0,43	0,28
Bank	Urgent	DSScheme	DS2	0,08	0,71	0,50	0,49	0,59	0,23
Bank	Urgent	DSScheme	DM137	0,10	0,71	0,51	0,52	0,62	0,20
Bank	Non-Urgent	DSScheme	DMEff	0,08	0,94	0,97	0,79	0,97	0,18
Bank	Non-Urgent	DSScheme	DS4	0,04	0,95	0,97	0,97	0,80	0,17
Bank	Non-Urgent	DSScheme	DM8	0,07	0,96	0,95	0,79	0,95	0,16
Bank	Non-Urgent	DSScheme	DMNU12pe	0,08	0,98	0,94	0,84	0,96	0,14
Bank	Non-Urgent	DSPF	DSScheme	0,05	0,95	0,74	0,96	0,93	0,22
Bank	Non-Urgent	DSTF	DSScheme	0,04	0,98	0,97	0,94	0,77	0,21

Table 6.24 - Two-way ANOVA for Spread in Scheme

H2-2c: The higher the variance in Ongoing, the higher the reliability

We have found no significance to support this hypothesis at the one-way ANOVA level, but at the two-way ANOVA level a low spread in Enactment yields the highest reliability (Table 6.25).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DS137	DS4	0,01	0,59	0,68	0,70	0,37	0,33
Bank	Urgent	DS137	DS1	0,05	0,60	0,63	0,77	0,46	0,31
Bank	Urgent	DS137	DM113	0,01	0,71	0,52	0,45	0,71	0,26
Bank	Non-Urgent	DS137	DS10	0,00	0,97	0,89	0,77	0,96	0,20

Bank	Non-Urgent	DS137	DM9	0,01	0,89	0,97	0,94	0,77	0,20
Bank	Non-Urgent	DS137	DM10	0,01	0,90	0,97	0,96	0,77	0,19
Bank	Non-Urgent	DS137	DS9	0,04	0,97	0,89	0,82	0,94	0,15
Bank	Non-Urgent	DS137	DM5	0,07	0,96	0,92	0,85	0,99	0,14
Bank	Non-Urgent	DS137	DM113	0,10	0,97	0,91	0,86	0,95	0,11
Bank	Non-urgent	DSPer	DS137	0,01	0,96	0,77	0,90	0,96	0,20

Table 6.25 - Two-way ANOVA for Spread in Enactment

Proposition 2-3

H2-3: Teams using richer media are more reliable.

No proof found for validation/falsification of this hypothesis neither at the one-dimensional level, nor for the urgent, or for the non-urgent incidents.

Proposition 2-4

H2-4a: Teams exhibiting a high propensity towards Team Orientation, relying on richer media yield a higher reliability.

H2-4b: Teams relying little on the dedicated IS and exhibiting a higher HRO propensity perform better than when they rely more on the dedicated IS.

Higher immediate registration in combination with a high homogeneity in HRO propensity results in the lowest reliability in the handling of urgent incidents (0.45 at $p \leq 0.05$). On the other hand, lower immediate registration in combination with a high homogeneity in HRO propensity results in the highest reliability (0.75 at $p \leq 0.05$), more particularly, the property of Deference to Expertise (0.52 vs. 0.78) and of Preoccupation with Failure (0.46 vs. 0.71). Remarkable is that in case of non-urgent incidents, the same observation can be made regarding the Preoccupation with Failure, but that a likewise high reliability (0.97) is obtained for the combination of a high degree of variance with a high degree of immediate registration ($p \leq 0.08$).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Max*	*Min*	*Spread*
Bank	PU12	DSHRT	DM10	0,05	0,75	0,45	0,58	0,61	0,75	0,45	0,30
Bank	PU12	DSDE	DM10	0,08	0,78	0,52	0,52	0,56	0,78	0,52	0,26
Bank	PU12	DSPF	DM10	0,07	0,71	0,46	0,59	0,66	0,71	0,46	0,25
Bank	PU3	DSPF	DM10	0,08	0,96	0,85	0,91	0,97	0,97	0,85	0,12

Table 6.26 - Two-way ANOVA for timeliness of incident registration

For urgent as well as non-urgent incidents, teams with a high homogeneity in incident management focus and a low reliance on Peregrine for their communication yield the best reliability whereas they yield the worst reliability when they do. For non-urgent incidents, a low proportion of time devoted to the handling of incidents in combination with a high degree of use of Peregrine yields the worst reliability, whereas in combination with a low reliance on Peregrine yields the best reliability.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Max*	*Min*	*Spread*
Bank	PU12	DS8	DMDed	0,00	0,40	0,69	0,67	0,46	0,69	0,40	0,29
Bank	PU3	DS8	DMDed	0,03	0,78	0,97	0,94	0,94	0,97	0,78	0,19
Bank	PU3	DM8	DMDed	0,08	0,81	0,96	0,95	0,95	0,96	0,81	0,15

Table 6.27 - Two-Way ANOVA for the use of dedicated IS and incident management focus

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Max*	*Min*	*Spread*
Bank	PU12	DSEff	DM10	0,02	0,79	0,51	0,47	0,55	0,79	0,47	0,32
Bank	PU12	DSTO	DM10	0,05	0,78	0,47	0,56	0,59	0,78	0,47	0,31
Bank	PU3	DS137	DM10	0,01	0,90	0,97	0,96	0,77	0,97	0,77	0,19

H2-4c: More experienced teams exhibiting a higher level of use of dedicated IS for their communication are more reliable

This hypothesis can be falsified. From Table 6.28 can be derived that teams with a high level of experience relying stronger on the dedicated IS (survey item 114, Peregrine) achieve a lower reliability (0.47) in the handling of urgent incidents. When they rely less on the dedicated IS their reliability is the highest (0.71). When less experienced teams rely heavily to face-to-face the yield the lowest reliability (0.48 for urgent incidents; 0.85 for non-urgent incidents).

Table 6.28 also shows that teams with more experience relying stronger on richer media, achieve a higher reliability: telephone (0.78); face-to-face (0.77); voice-based systems (0.76).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DM5	DM112	0,01	0,61	0,52	0,42	0,78	0,37
Bank	Urgent	DM5	DM111	0,02	0,70	0,48	0,58	0,77	0,30
Bank	Urgent	DM5	DMVoic	0,02	0,64	0,49	0,51	0,76	0,27
Bank	Urgent	DM5	DM114	0,06	0,51	0,63	0,71	0,47	0,24
Bank	Urgent	DM5	DMFac	0,06	0,67	0,48	0,56	0,71	0,23

Bank	Non-Urgent	DM5	DMFac	0,07	0,96	0,85	0,92	0,98	0,13
Bank	Non-Urgent	DM5	DMVoic	0,08	0,94	0,86	0,91	0,98	0,13

Table 6.28 - Two-way ANOVA for Experience (DM5) and use of communication tools (DM112)

Proposition 2-5

Proposition 2-5: The better the fit between SeMa propensity and IS use, the higher the reliability.

H2-5: Teams relying little on the dedicated IS and exhibiting a higher SeMa propensity perform better than when they rely more on dedicated IS.

We have found no significance to support this hypothesis at any ANOVA level.

Proposition 2-6

H2-6a: Teams that work under close physical proximity perform better than teams that do not.

We have tested this variable by ranking the answer possibilities from little physical proximity to the IT headquarters, to high proximity. We have found evidence for the hypothesis on two levels: (1) proximity to the Bank's IT headquarters (DM4) and (2) team dispersion (DS4).

1. Teams that (on average) are more based in the Bank's IT headquarters are performing better than teams that aren't (DM4) (Table 6.29). These observations apply to the handling of urgent as well as non-urgent incidents.

Case	*Type*	*Fact1*	*Sig.*	*LL*	*LH*	*Spread*
Bank	Non-Urgent	DM4	0,07	0,89	0,97	0,08
Bank	Urgent	DM4	0,04	0,54	0,73	0,19

Table 6.29 - One-way ANOVA for vicinity to IT headquarters

Despite its level of significance that strictly speaking is not acceptable for further analysis ($p = 0.11$) we do want to point out the link with the Preoccupation with Failure construct, notably for urgent incidents. From Table 6.30 we derive that teams with a high degree of Preoccupation with Failure that are working in vicinity to the company headquarters are the most reliable. On the other hand, this high degree of Preoccupation with Failure yields the lowest process reliability when they are not working in vicinity to the IT headquarters.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DMPF	DM4	0,11	0,58	0,59	0,45	0,79	0,34

Table 6.30 - Two-way ANOVA for vicinity to IT headquarters

2. A low spread in physical proximity is better for process reliability (DS4) (Table 6.31).

Case	*Type*	*Fact1*	*Sig.*	*LL*	*LH*	*Spread*
Bank	Non-Urgent	DS4	0,03	0,96	0,85	0,10

Table 6.31 - One-way ANOVA for spread in Physical Proximity

Also at the two-way ANOVA level, the results are interesting (Table 6.32 and Table 6.33) because of the general observation that low spread in physical location – i.e. a low team dispersion – yields the highest reliability. This is particularly true for the non-urgent incidents. We also notice that reliability is the lowest when team dispersion is high. For the urgent incidents this effect of team dispersion is countered by the impact of workload.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DS4	DMNU12pe	0,01	0,57	0,66	0,24	0,72	0,48
Bank	Urgent	DS4	DM113	0,10	0,69	0,58	0,44	0,64	0,25
Bank	Non-Urgent	DS4	DMEff	0,02	0,94	0,97	0,74	0,97	0,23
Bank	Non-Urgent	DS4	DMNU3pe	0,01	0,94	0,97	0,74	0,97	0,23
Bank	Non-Urgent	DS4	DMNUApe	0,01	0,94	0,97	0,74	0,97	0,23
Bank	Non-Urgent	DS4	DS111	0,06	0,97	0,94	0,77	0,92	0,20
Bank	Non-Urgent	DS4	DSFac	0,06	0,96	0,95	0,77	0,92	0,20
Bank	Non-Urgent	DS4	DMNU12pe	0,02	0,97	0,94	0,78	0,96	0,20
Bank	Non-Urgent	DS4	DS8	0,08	0,96	0,95	0,77	0,92	0,19
Bank	Non-Urgent	DS4	DS114	0,05	0,97	0,95	0,79	0,95	0,18
Bank	Non-Urgent	DS4		0,03	0,96	0,85			0,10

Table 6.32 - Two-way ANOVA for spread in Physical Proximity

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DSTF	DS4	0,02	0,71	0,83	0,57	0,35	0,48
Bank	Urgent	DS137	DS4	0,01	0,59	0,68	0,70	0,37	0,33
Bank	Urgent	DSScheme	DS4	0,07	0,60	0,67	0,71	0,43	0,28

Bank	Non-Urgent	DSSeMa	DS4	0,01	0,95	0,98	0,97	0,77	0,21
Bank	Non-Urgent	DSTF	DS4	0,04	0,97	0,98	0,94	0,77	0,21
Bank	Non-Urgent	DSScheme	DS4	0,04	0,95	0,97	0,97	0,80	0,17

Table 6.33 - Two-way ANOVA for spread in Physical Proximity

H2-6b: Larger teams are more reliable than smaller teams.

We have found no evidence for this hypothesis at the one-way ANOVA level. At the two-way level, Table 6.34 shows an interaction with time allocated to incident handling work. This observation is dealt with next.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DM6	DM8	0,05	0,50	0,73	0,66	0,54	0,23

Table 6.34 - Two-way ANOVA for Team Size

H2-6c: Teams with higher incident workload are more reliable than teams with a lower workload.

This hypothesis can be validated from Table 6.35, as well concerning the workload regarding the handling of urgent incidents (0.68) as non-urgent incidents (0.97). Results from the two-way ANOVA support this finding with the exception of the combination with a high heterogeneity in the use of Peregrine for communication where a low workload shows the highest reliability (Table 6.36).

Case	*Type*	*Fact1*	*Sig.*	*LL*	*LH*	*Spread*
Bank	Urgent	DMNU12pe	0,00	0,43	0,68	0,25
Bank	Non-Urgent	DMNU3pe	0,02	0,87	0,97	0,10
Bank	Non-Urgent	DMNUApe	0,03	0,87	0,97	0,10

Table 6.35 - One-way ANOVA of Workload

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DS4	DMNU12pe	0,01	0,57	0,66	0,24	0,72	0,48
Bank	Urgent	DSScheme	DMNU12pe	0,00	0,59	0,62	0,29	0,77	0,48
Bank	Urgent	DS114	DMNU12pe	0,02	0,28	0,71	0,55	0,62	0,43
Bank	Urgent	DM111	DMNU12pe	0,09	0,55	0,69	0,27	0,67	0,42
Bank	Urgent	DS112	DMNU12pe	0,08	0,31	0,71	0,49	0,60	0,40

Bank	Urgent	DMTF	DMNU12pe	0,10	0,59	0,70	0,30	0,65	0,40
Bank	Urgent	DMSeMa	DMNU12pe	0,07	0,34	0,72	0,54	0,64	0,38
Bank	Urgent	DM1	DMNU12pe	0,10	0,56	0,66	0,32	0,69	0,36
Bank	Urgent	DS1	DMNU12pe	0,06	0,62	0,68	0,33	0,68	0,35
Bank	Non-Urgent	DM1	DMNU12pe	0,01	0,97	0,94	0,76	0,95	0,21
Bank	Non-Urgent	DS112	DMNU12pe	0,02	0,76	0,96	0,95	0,92	0,20
Bank	Non-Urgent	DS4	DMNU12pe	0,02	0,97	0,94	0,78	0,96	0,20
Bank	Non-Urgent	DS1	DMNU12pe	0,04	0,98	0,95	0,80	0,95	0,18
Bank	Non-Urgent	DS114	DMNU12pe	0,04	0,81	0,96	0,97	0,92	0,15
Bank	Non-Urgent	DMTF	DMNU12pe	0,08	0,97	0,94	0,83	0,96	0,14
Bank	Non-Urgent	DSMSA	DMNU12pe	0,08	0,98	0,94	0,84	0,96	0,14
Bank	Non-Urgent	DSSeMa	DMNU12pe	0,08	0,98	0,94	0,84	0,96	0,14

Table 6.36 - Two-way ANOVA of Workload concerning the handling of urgent incidents

H2-6d: Teams with a greater deal of their time allocated to incident management are more reliable than teams with smaller time allocation.

We have found no evidence for this assertion at the one-way ANOVA level. At the two-way ANOVA level (Table 6.37) there is sufficient evidence that a low degree of time allocation leads to low reliability.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DM8	DM6	0,05	0,50	0,66	0,73	0,54	0,23
Bank	Non-Urgent	DM8	DMNU3pe	0,10	0,80	0,97	0,93	0,97	0,17
Bank	Non-Urgent	DM8	DMDed	0,08	0,81	0,96	0,95	0,95	0,15
Bank	Non-Urgent	DM8	DSMSA	0,07	0,96	0,79	0,95	0,95	0,16
Bank	Non-Urgent	DM8	DM1	0,08	0,96	0,81	0,95	0,95	0,16

Table 6.37 - Two-way ANOVA of Time Allocation

Proposition 2-7

Proposition 2-7: The better the fit between HRO propensity and the structural organization dimension use, the higher the reliability.

H2-7a: A high HRO propensity enhances the effect on reliability of teams working under close physical proximity

H2-7b: A high HRO propensity enhances the effect on reliability of larger teams

H2-7c: A high HRO propensity enhances the effect on reliability of teams with higher incident workload.

H2-7a: A high HRO propensity enhances the effect on reliability of teams working under close physical proximity

Case	Type	Fact1	Sig.	LL	LH
Bank	Non-Urgent	DM4	0,07	0,89	0,97
Bank	Urgent	DM4	0,04	0,54	0,73
Bank	Non-urgent	DS4	0.03	0.96	0.85

Table 6.38 - One-way ANOVA for Proximity

This hypothesis can be validated at an acceptable level of significance for urgent incidents. A low value for spread in vicinity (i.e. close proximity) results in the highest performance (Table 6.38).

We notice also that the more a team is based in the vicinity of headquarters, themore reliable it is.

H2-7b: A high HRO propensity enhances the effect on reliability of larger teams

This hypothesis cannot be validated at an acceptable level of significance.

H2-7c: A high HRO propensity enhances the effect on reliability of teams with higher incident workload.

Case	Type	Fact1	Sig.	LL	LH
Bank	Urgent	DMNU12pe	0,00	0,43	0,68
Bank	Non-Urgent	DMNU3pe	0,02	0,87	0,97
Bank	Non-Urgent	DMNUApe	0,03	0,87	0,97

Table 6.39 - Workload

This hypothesis can be validated. We see from Table 6.39 that a high workload has a strong effect on high reliability, as well for the handling of urgent as non-urgent incidents.

Proposition 2-8

Proposition 2-8: The better the fit between SeMa propensity and the structural organization dimension use, the higher the reliability.

H2-8a: A high SeMa propensity enhances the effect on reliability of teams working under close physical proximity.

No validation possible at an acceptable level of significance.

H2-8b: A high SeMa propensity enhances the effect on reliability of larger teams.

No validation possible at an acceptable level of significance

Proposition 2-9

H2-9a: More experienced teams are more reliable.

No validation of this effect at acceptable levels of significance can be observed.

H2-9b: The higher the variance in HRO propensity, the higher the reliability

We have found no support for this hypothesis at a sufficient level of significance on the one-way analysis level. On the two-way ANOVA level (Table 6.40) we notice that the highest reliability is achieved low spread in HRO propensity in combination with highly experienced teams (0.72 for urgent, and 0.98 for non-urgent incidents), high use of e-mail (0.66 for urgent incidents and 0.97 for non-urgent incidents). The lowest reliability is achieved for low spread in HRO propensity in combination with a less experienced teams (0.43 for urgent incidents and 0.85 for non-urgent incidents) and little use of e-mail (0.45 for urgent incidents and 0.88 for non-urgent incidents).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DSHRT	DM10	0,05	0,75	0,45	0,58	0,61	0,30
Bank	Urgent	DSHRT	DM5	0,03	0,43	0,72	0,62	0,51	0,29
Bank	Urgent	DSHRT	DS10	0,07	0,48	0,77	0,61	0,57	0,28
Bank	Urgent	DSHRT	DM9	0,05	0,69	0,50	0,53	0,71	0,21
Bank	Urgent	DSHRT	DS9	0,05	0,50	0,69	0,71	0,53	0,21
Bank	Urgent	DSHRT	DM113	0,08	0,45	0,66	0,63	0,51	0,21
Bank	Non-Urgent	DSHRT	DM5	0,07	0,85	0,98	0,93	0,88	0,13
Bank	Non-Urgent	DSHRT	DM113	0,08	0,88	0,97	0,94	0,86	0,11

Table 6.40 - Two-way ANOVA for Spread in HRO propensity

Case	Type	Fact1	Fact2	Sig.	LL	LH	HL	HH	Spread
Bank	Urgent	DSDE	DSHRT	0,03	0,55	0,78	0,67	0,50	0,28
Bank	Urgent	DSPer	DSHRT	0,06	0,48	0,62	0,77	0,57	0,28
Bank	Non-Urgent	DSSO	DSHRT	0,10	0,98	0,88	0,86	0,92	0,12

Table 6.41 - Two-way ANOVA for Spread in HRT

H2-9c: The higher the variance in Team Orientation, the higher the reliability

This hypothesis cannot be validated at the one-way ANOVA level. On the two-dimensional level (Table 6.42), the highest reliability can be found for urgent incidents for low spread in Team Orientation in combination with low score on Enactment (0.76), on registration in Peregrine (0.78)and for non-urgent incidents for low spread in enactment as well (0.98). A low score on spread in Team Orientation in combination with a high spread in registration in Peregrine (0.80).

Case	Type	Fact1	Fact2	Sig.	LL	LH	HL	HH	Spread
Bank	Urgent	DSTO	DM137	0,01	0,76	0,43	0,53	0,64	0,33
Bank	Urgent	DSTO	DM10	0,05	0,78	0,47	0,56	0,59	0,31
Bank	Urgent	DSTO	DS10	0,06	0,50	0,80	0,59	0,56	0,30
Bank	Urgent	DSTO	DSDE	0,04	0,57	0,68	0,73	0,47	0,25
Bank	Non-Urgent	DSTO	DSDE	0,06	0,90	0,98	0,96	0,87	0,11
Bank	Non-Urgent	DSTO	DM137	0,10	0,98	0,87	0,90	0,94	0,11
Bank	Non-Urgent	DSTO	DM113	0,11	0,88	0,97	0,94	0,87	0,10

Table 6.42 - Two-way ANOVA for spread in Team Orientation

H2-9d: The higher the variance in Threat Flexibility, the higher the reliability.

Case	Type	Fact1	Sig.	LL	LH	Spread
Bank	Non-Urgent	DSTF	0,02	0,97	0,87	0,10
Bank	Urgent	DSTF	0,00	0,74	0,48	0,26

Table 6.43 - One-way ANOVA for Threat Flexibility

This hypothesis is falsified. As well for urgent as for non-urgent incidents, the lowest variance yields the highest reliability (Table 6.43).

H2-9e: The higher the variance in Preoccupation with Failure, the higher the reliability

This hypothesis could not be validated at the one-way ANOVA level. At the two-dimensional level, a low spread in Preoccupation with Failure generally yields the lowest reliability (Table 6.44).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DSPF	DS10	0,01	0,41	0,72	0,69	0,53	0,30
Bank	Urgent	DSPF	DSSO	0,02	0,69	0,39	0,56	0,65	0,30
Bank	Urgent	DSPF	DM10	0,07	0,71	0,46	0,59	0,66	0,25
Bank	Urgent	DSPF	DM5	0,10	0,46	0,67	0,64	0,55	0,22
Bank	Non-Urgent	DSPF	DSScheme	0,05	0,95	0,74	0,96	0,93	0,22
Bank	Urgent	DSPF	DM113	0,07	0,46	0,64	0,67	0,52	0,21
Bank	Non-Urgent	DSPF	DS10	0,04	0,83	0,96	0,97	0,91	0,14
Bank	Non-Urgent	DSPF	DM113	0,07	0,84	0,95	0,96	0,90	0,12
Bank	Non-Urgent	DSPF	DS9	0,10	0,85	0,94	0,97	0,90	0,12
Bank	Non-Urgent	DSPF	DM10	0,08	0,96	0,85	0,91	0,97	0,12

Table 6.44 - Two-way ANOVA for Preoccupation with Failure

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DSPer	DSPF	0,03	0,46	0,69	0,71	0,57	0,25
Bank	Non-Urgent	DSPer	DSPF	0,09	0,85	0,96	0,96	0,92	0,12

Table 6.45 - Two-way ANOVA for Spread in Preoccupation with Failure

H2-9f: The higher the variance in Sensitivity to Operations, the higher the reliability

This hypothesis cannot be validated at the one-way ANOVA level. For urgent incidents, a combination of low spread in Sensitivity to Operations and a low spread in Preoccupation with Failure yields the highest reliability (0.69) (Table 6.46).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Non-Urgent	DSSO	DSHRT	0,10	0,98	0,88	0,86	0,92	0,12
Bank	Urgent	DSPF	DSSO	0,02	0,69	0,39	0,56	0,65	0,30

Table 6.46 - Two-way ANOVA for spread in Sensitivity to Operations

H2-9g: The higher the variance in Deference to Expertise, the higher the reliability

This hypothesis could not be validated at the one-way ANOVA level. On the two-dimensional interpretation, we notice that the highest reliability is achieved for the combinations of low spread in Deference to Expertise and other factors, especially for urgent incidents (Table 6.47).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
Bank	Urgent	DSDE	DMScheme	0,01	0,77	0,56	0,43	0,66	0,34
Bank	Urgent	DSDE	DMSeMa	0,01	0,72	0,55	0,41	0,65	0,31
Bank	Urgent	DSDE	DSHRT	0,03	0,55	0,78	0,67	0,50	0,28
Bank	Urgent	DSDE	DS10	0,09	0,54	0,80	0,56	0,52	0,27
Bank	Urgent	DSDE	DM10	0,08	0,78	0,52	0,52	0,56	0,26
Bank	Urgent	DSDE	DMSO	0,03	0,71	0,59	0,44	0,69	0,26
Bank	Urgent	DSDE	DM137	0,05	0,73	0,49	0,49	0,59	0,24
Bank	Non-Urgent	DSDE	DMHRT	0,02	0,97	0,87	0,84	0,96	0,13
Bank	Non-Urgent	DSDE	DMSO	0,04	0,97	0,89	0,86	0,98	0,12
Bank	Non-Urgent	DSDE	DS113	0,08	0,97	0,87	0,87	0,94	0,10
Bank	Urgent	DSTO	DSDE	0,04	0,57	0,68	0,73	0,47	0,25
Bank	Non-Urgent	DSTO	DSDE	0,06	0,90	0,98	0,96	0,87	0,11

Table 6.47 - Two-way ANOVA for Spread in Deference to Expertise

Proposition 2-10

H2-10a: Teams that perceive Threat Flexibility more homogenously perform better than teams that do not.

At the same time we notice (Table 6.48) that a high homogeneity (i.e. low spread/variance) in the perception of the Threat Flexibility construct yields the highest reliability, as well for the handling of urgent (0.74 at $p \leq 0.05$) as of the non-urgent incidents (0.97 at $p \leq 0.01$).

Case	*Type*	*Fact1*	*Sig.*	*LL*	*LH*	*Spread*
Bank	PU3	DSTF	0,02	0,97	0,87	0,10
Bank	PU12	DSTF	0,00	0,74	0,48	0,26

Table 6.48 - One-way ANOVA for spread of Threat Flexibility

H2-10b: Teams that perceive efficiency drivenness more homogenously perform better than teams that do not.

We notice that the higher the homogeneity in the perception of efficiency drivenness, the higher the reliability. The significance is sufficiently strong (p=0.07), as can be derived from (Table 6.49), to demonstrate the importance of a low degree of variance in the perception of efficiency orientation to

Case	*Type*	*Fact1*	*Sig.*	*LL*	*LH*	*Spread*
Bank	PU12	DSEff	0,07	0,67	0,52	0,16

Table 6.49 - One-way ANOVA for spread of efficiency drivenness

Propostion 2-11

Proposition 2-11: The better the fit between SeMa propensity and variety, the higher the reliability.

H2-11: More Eperienced teams, relying more on SeMa propensity, are more reliable.

This hypothesis could not be validated at an acceptable level of significance.

3.2 NPP Case

Proposition 2-1

H2-1a: Teams exhibiting a higher propensity towards Team Orientation yield higher reliability in the handling of urgent incidents, whereas this is counterproductive for the handling of non-urgent incidents.

No effect found at an acceptable level of significance.

H2-1b: Teams exhibiting a high propensity towards Team Orientation and exhibiting a high degree of Sensitivity to Operations yield a higher reliability than teams than the same teams exhibiting a low degree of Sensitivity to Operations.

No evidence found to validate the hypothesis.

H2-1c: The higher the average Threat Flexibility, the higher the reliability.

The highest reliability (Table 6.50) is achieved by teams with a high score on Threat Flexibility in combination with a high score on SenseMaking and HRT constructs, regardless of the incident type. Remarkable in this respect is the observation that a low degree of Threat Flexibility in combination with a low score on SenseMaking and HRT constructs yields – for urgent incidents with 0.93 and for non-urgent incidents with 0.67 to 0.71 only 0.04 lower – a high reliability as well.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DMTF	DMSeMa	0,10	0,93	0,56	0,83	0,97	0,42
NPP	Urgent	DMTF	DMSO	0,07	0,93	0,48	0,84	0,97	0,49
NPP	Urgent	DMTF	DMOther	0,06	0,93	0,48	0,77	0,97	0,49
NPP	Non-Urgent	DMTF	DMHRT	0,08	0,67	-0,21	0,25	0,76	0,97
NPP	Non-Urgent	DMTF	DMTO	0,10	0,69	-0,25	0,46	0,74	0,99
NPP	Non-Urgent	DMTF	DMSO	0,07	0,71	-0,29	0,42	0,76	1,05

Table 6.50 - Two-way ANOVA for Threat Flexibility

H2-1d: Teams that operate in a less restrictive (more supportive) organizational climate perform better than teams that do not.

We have found no significant proof for this hypothesis since the construct covering the degree of supportiveness namely Threat Flexibility. Nor for the urgent incidents, nor for the non-urgent incidents is it so that the degree of restrictiveness/supportiveness of Threat Flexibility is positively influencing reliability, regardless of any mediating variable.

Proposition 2-2

H2-2a: The higher the variance in SeMa propensity, the higher the reliability

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DM32	DSSeMa	0,07	0,92	0,94	0,96	0,45	0,51
NPP	Urgent	DMSeMa	DSSeMa	0,02	0,87	0,92	0,97	0,36	0,61
NPP	Urgent	DS9	DSSeMa	0,02	0,91	0,94	0,96	0,33	0,63
NPP	Urgent	DS8	DSSeMa	0,04	0,92	0,32	0,96	0,97	0,65
NPP	Urgent	DS10	DSSeMa	0,10	0,99	0,84	0,91	0,12	0,87
NPP	Non-Urgent	DMTeamSize	DSSeMa	0,08	0,60	0,69	0,78	-0,29	1,08
NPP	Non-Urgent	DM32	DSSeMa	0,07	0,58	0,69	0,81	-0,30	1,11
NPP	Non-Urgent	DS4	DSSeMa	0,10	0,74	0,69	0,59	-0,54	1,28

Table 6.51 - Two-way ANOVA for SenseMaking

We have found no evidence for this assumption at the one-way ANOVA level. At the two way level ANOVA however, this hypothesis can be falsified. In general, it can be derived from Table 6.51 that the higher the spread in SenseMaking, the lower the incident management reliability. More particularly, in the case of the handling of urgent incidents, a high homogenous degree of

SenseMaking propensity leads to the highest reliability (0.97), whereas a high but heterogeneous degree of SenseMaking propensity leads to the lowest reliability (0.36).

H2-2b: The higher the variance in making sense of Other, the higher the reliability.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DSOther	DSSupRes	0,06	0,89	0,96	0,94	0,47	0,49
NPP	Urgent	DSOther	DSPres	0,04	0,91	0,97	0,32	0,96	0,65

We have found no significant evidence for this hypothesis at the one-way ANOVA level. At the two-way ANOVA level we can falsify the hypothesis. A high variance in Other results in high reliability in combination with a low (0.94) spread in the perception of the availability of Supplementary Resources or with a high variance in the perception of Pressure (0.97). A low variance in Other results in high reliability in combination with a high (0.96) or low (0.94) spread in the perception of the availability of Supplementary Resources or with a high variance in the perception of Pressure (0.97).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DS32	DSScheme	0,11	0,94	0,52	0,92	0,97	0,45
NPP	Urgent	DS31	DSScheme	0,06	0,97	0,52	0,88	0,97	0,45
NPP	Urgent	DN0pe	DSScheme	0,07	0,96	0,52	0,90	0,98	0,46
NPP	Urgent	DM114	DSScheme	0,06	0,88	0,95	0,96	0,47	0,49
NPP	Urgent	DN123pe	DSScheme	0,07	0,91	0,43	0,95	0,97	0,55
NPP	Urgent	DM31	DSScheme	0,02	0,95	0,34	0,91	0,95	0,61
NPP	Non-Urgent	Dmvoic	DSScheme	0,10	0,83	0,33	0,13	0,82	0,69
NPP	Non-Urgent	DMSupRes	DSScheme	0,09	0,79	0,29	0,16	0,87	0,71
NPP	Non-Urgent	DM115	DSScheme	0,11	0,84	0,35	0,12	0,78	0,72
NPP	Non-Urgent	DMPF	DSScheme	0,07	0,08	0,82	0,66	0,13	0,74
NPP	Non-Urgent	DMOther	DSScheme	0,06	0,05	0,81	0,79	0,26	0,76
NPP	Non-Urgent	DS115	DSScheme	0,10	0,81	0,33	0,04	0,79	0,77
NPP	Non-Urgent	DS31	DSScheme	0,09	0,81	0,34	0,03	0,73	0,78
NPP	Non-Urgent	DSDE	DSScheme	0,06	0,01	0,77	0,84	0,29	0,83
NPP	Non-Urgent	DSDE	DSScheme	0,06	0,01	0,84	0,77	0,29	0,83

Table 6.52 - Two-way ANOVA for Scheme

H2-2c: The higher the variance in Ongoing, the higher the reliability

This hypothesis can be validated (0.75) at the two-way ANOVA level where the combination of larger teams and a more heterogeneous enactment results in the highest reliability (0.75) whereas the combination of larger teams and a more homogenous enactment results in the lowest reliability (-0.52).

More female teams that exhibit more enactment properties are highly reliable (0.91) whereas they are less reliable (-1.02) when they exhibit less enactment properties. More male teams are relatively indifferent (0.50 vs. 0.69) towards the enactment properties.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Non-Urgent	DMTeamSize	DS137	0,06	0,64	0,66	-0,52	0,75	1,27
NPP	Non-Urgent	DM2	DS137	0,08	0,50	0,69	-1,02	0,91	1,93

Table 6.53 - Two-way ANOVA for Enactment

Proposition 2-3

H2-3: Teams using richer media are more reliable.

This hypothesis can be validated for non-urgent incidents. Teams that show a diversified use of telephone in the handling of incidents (in general) achieve a higher reliability (0.85) than teams that have the same tendency (regardless of the kind of inclination, positive or negative) towards the reliance on telephone.

Case	*Type*	*Fact1*	*Sig.*	*LL*	*LH*	*Spread*
NPP	Non-Urgent	DS112	0,0140859	0,02	0,85	0,83

Table 6.54 - One-way ANOVA for spread in the use of telephone

Proposition 2-4

H2-4a: Teams exhibiting a high propensity towards Team Orientation, relying on richer media yield a higher reliability.

From Table 6.55 can be derived that teams with a high degree of Team Orientation and a high degree of reliance on face-to-face communication yield the highest reliability in the handling of urgent incidents. This reliability is very high (0.94). When these teams rely little on face-to-face communication their reliability drops considerably (with 0.56 to 0.39). The reliability of teams with a smaller degree of Team Orientation is independent from the degree of reliance on face-to-face communication (0.88).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DMFac	DMTO	0,09	0,88	0,39	0,88	0,94	0,56

Table 6.55 - Two-way ANOVA Team Orientation & Media Richness

H2-4b: Teams relying little on the dedicated IS and exhibiting a higher HRO propensity perform better than when they rely more on the dedicated IS.

Teams whose management expects they rigorously stick to procedures (low score on 243INV) and that homogenously rely on dedicated IS in the handling of incidents score the highest reliability in the handling of urgent incidents (0.96, which is very high) (Table 6.56). When these teams are less homogenous in the way they rely on dedicated IS, their reliability drops considerably (0.40). This underlines the relevance of the hypothesis as a guideline for the design of information systems (in its broadest sense of hardware, software and procedures). Teams whose management allows team members to deviate more from procedure and that exhibit a high variance in the way they make use of dedicated IS (0.93, also very high).

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DM243INV	DSDed	0,07	0,96	0,40	0,87	0,93	0,56

Table 6.56 - Deviation from procedure & Tool dedication

H2-4c: More experienced teams exhibiting a higher level of use of dedicated IS for their communication are more reliable.

No evidence can be found for this assertion at an acceptable level of significance.

Proposition 2-5

Proposition 2-5: The better the fit between SeMa propensity and IS use, the higher the reliability.

H2-5: Teams relying little on the dedicated IS and exhibiting a higher SeMa propensity perform better than when they rely more on dedicated IS.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*
NPP	Non-Urgent	Dmvoic	DSScheme	0,10	0,83	0,33	0,13	0,82
NPP	Non-Urgent	Dmvoic	DSSelf	0,10	0,82	0,33	0,18	0,91
NPP	Urgent	Dmvoic	DSDed	0,01	0,97	0,23	0,85	0,93
NPP	Non-Urgent	Dmvoic	DSDed	0,06	0,85	-0,29	0,09	0,53
NPP	Urgent	Dmvoic	DSVoic	0,00	0,91	-0,74	0,93	0,89
NPP	Non-Urgent	Dmvoic	DS2	0,03	0,50	0,91	0,71	-1,02
NPP	Non-Urgent	Dmvoic	DS1	0,03	0,50	0,91	0,60	-1,55
NPP	Non-Urgent	Dmvoic	DSVoic	0,00	0,81	-2,26	0,04	0,44

Table 6.57 - Two-way Anova for SeMa and Is Use

We see from Table 6.57 that this hypothesis cannot be validated. However, we notice that a high spread in the SeMa propensity Scheme (DSScheme), i.e. a high homogeneity in combination with a high reliance on voice-based communication tools yields the lowest performance.

Proposition 2-6

H2-6a: Teams that work under close physical proximity perform better than teams that do not.

In the NPP Case, no data are available to test this hypothesis. Testing would be senseless because all team-members are housed in the same physical location.

H2-6b: Larger teams are more reliable than smaller teams.

We have found no proof for the validation of this hypothesis at the one-way ANOVA level.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DMPres	DMTeamSize	0,10	0,89	0,96	0,97	0,54	0,43
NPP	Urgent	DMFac	DMTeamSize	0,06	0,96	0,47	0,89	0,96	0,49
NPP	Urgent	DMSupRes	DMTeamSize	0,04	0,96	0,46	0,89	0,97	0,51
NPP	Urgent	DM114	DMTeamSize	0,01	0,88	0,96	0,96	0,34	0,62
NPP	Non-Urgent	DMSO	DMTeamSize	0,05	0,54	0,87	0,84	-0,18	1,05
NPP	Non-Urgent	DMHRT	DMTeamSize	0,03	0,46	0,79	0,83	-0,30	1,13
NPP	Non-Urgent	DSSupRes	DMTeamSize	0,09	0,54	0,79	0,83	-0,12	0,95
NPP	Non-Urgent	DSOther	DMTeamSize	0,09	0,77	-0,15	0,55	0,83	0,97
NPP	Non-Urgent	DSSO	DMTeamSize	0,06	0,48	0,80	0,86	-0,12	0,98
NPP	Non-Urgent	DSSeMa	DMTeamSize	0,08	0,60	0,78	0,69	-0,29	1,08
NPP	Non-Urgent	DMEff	DMTeamSize	0,10	0,65	-0,30	0,64	0,79	1,09
NPP	Non-Urgent	DM112	DMTeamSize	0,09	0,64	-0,33	0,65	0,81	1,14
NPP	Non-Urgent	DMTO	DMTeamSize	0,02	0,50	0,84	0,83	-0,35	1,19
NPP	Non-Urgent	DS137	DMTeamSize	0,06	0,64	-0,52	0,66	0,75	1,27

Table 6.58 - Two-way ANOVA for Team Size

At the two-way ANOVA analysis level, it can be derived from Table 6.58 that in the majority of cases where team size moderates the effect of the independent variable on the dependent variable, large teams yield a lower reliability than small teams.

For urgent incidents, the highest reliability (0.97) is obtained by small teams that perceive high pressure, whereas small teams that perceive little pressure still yield a high reliability score (0.89). Large teams perceiving high pressure yield the lowest reliability (0.54), and large teams perceiving low pressure manage to be very reliable (0.96).

Small teams relying little on face-to-face communication are the most reliable (0.96); large teams the least (0.47) in the handling of urgent incidents. Large teams, for that matter, can consistently increase their reliability when they (contrary to small teams), rely on face-to-face communication for the handling of urgent incidents.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DM114	DMTeamSize	0,01	0,88	0,96	0,96	0,34	0,62

Table 6.59 - Two-way ANOVA for TeamSize (ctd)

Big teams communicating considerably through the dedicated system, yield the lowest reliability (0.34), whereas big teams that do not do so, see their reliability increase spectacularly (to 0.96). Small teams relying heavily on the dedicated system are the most reliable.

H2-6c: Teams with higher incident workload are more reliable than teams with a lower workload.

We have been able to validate this hypothesis. Interestingly, Table 6.60 shows that the number of non-urgent notifications per employee is explaining the high reliability in the handling of urgent incidents.

Case	*Type*	*Fact1*	*Sig.*	*LL*	*LH*	*Spread*
NPP	Urgent	DN123pe	0,09	0,71	0,96	0,26

Table 6.60 - One-way ANOVA for Workload (NPP)

H2-6d: Teams with a greater deal of their time allocated to incident management are more reliable than teams with smaller time allocation.

In the NPP Case, no data are available to test this hypothesis. Testing would be senseless because the large majority of teams in the survey are part of the Maintenance department, meaning that their time allocation would approach 100 percent.

Proposition 2-7

Proposition 2-7: The better the fit between HRO propensity and the structural organization dimension use, the higher the reliability.

H2-7a: A high HRO propensity enhances the effect on reliability of teams working under close physical proximity

H2-7b: A high HRO propensity enhances the effect on reliability of larger teams

H2-7c: A high HRO propensity enhances the effect on reliability of teams with higher incident workload.

H2-7a: A high HRO propensity enhances the effect on reliability of teams working under close physical proximity

This hypothesis cannot be tested in the NPP, since physical proximity is a given.

H2-7b: A high HRO propensity enhances the effect on reliability of larger teams

No validation possible at an acceptable level of significance.

H2-7c: A high HRO propensity enhances the effect on reliability of teams with higher incident workload.

Case	**Type**	**Fact1**	**Sig.**	**LL**	**LH**
NPP	Urgent	DN123pe	0,09	0,71	0,96

Table 6.61 - Workload (NPP)

This hypothesis can be validated (**Table 6.61**).

Proposition 2-8

Proposition 2-8: The better the fit between SeMa propensity and the structural organization dimension use, the higher the reliability.

H2-8a: A high SeMa propensity enhances the effect on reliability of teams working under close physical proximity.

No data available to test this hypothesis.

H2-8b: A high SeMa propensity enhances the effect on reliability of larger teams

No data available to test this hypothesis.

Proposition 2-9

H2-9a: More experienced teams are more reliable.

This hypothesis can be falsified at an acceptable level of significance (p ≤ 0.08). From Table 6.62 can be seen that teams with a lower level of experience perform better in the handling of urgent incidents. A side remark is that the difference between the average reliability of on average less experienced and more experienced teams is small (0.26 as compared to a minimum of 0.25 and a maximum of 0.29).

Case	*Type*	*Fact1*	*Sig.*	*LL*	*LH*	*Spread*
NPP	Urgent	DM5	0,08	0,97	0,70	0,26

Table 6.62 - One-way ANOVA of Experience

H2-9b: The higher the variance in HRO propensity, the higher the reliability

There is no evidence at an acceptable level of significance for this assertion at the one-dimensional level. However, on the two-way ANOVA level, there is evidence for the hypothesis (Table 6.63).

Regarding the handling of urgent incidents, the combination of a high variance in the spread of HRT propensity and a high spread in the degree to which team members adjust procedures leads to the lowest reliability (0.45). Other combinations are less pronounced since they range only 0.07 (0.89 to 0.96). Nevertheless, the lowest of these reliabilities (0.89) can be observed for the combination of a low variance in the spread of HRT propensity and a low spread in the degree to which team members adjust procedures.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Non-Urgent	DSHRT	DSTF	0,09	0,40	0,80	0,86	0,05	0,81
NPP	Non-Urgent	DSHRT	DSOther	0,06	0,72	0,42	-0,10	0,87	0,97
NPP	Urgent	DSHRT	DS9	0,06	0,89	0,96	0,95	0,45	0,51
NPP	Non-Urgent	DSHRT	DMHRT	0,08	0,39	0,75	0,81	-0,04	0,86
NPP	Non-Urgent	DSHRT	DMTO	0,10	0,46	0,72	0,83	-0,06	0,89
NPP	Non-Urgent	DSHRT	DMSO	0,09	0,47	0,71	0,84	-0,07	0,92
NPP	Non-Urgent	DSHRT	DM32	0,04	0,44	0,83	0,90	-0,13	1,03
NPP	Non-Urgent	DSHRT	DMEff	0,04	0,62	0,32	-0,47	0,81	1,28

Table 6.63 - Two-way ANOVA for spread in HRO propensity

Regarding the handling of non-urgent incidents, the combination of a high spread in HRO propensity and a high spread in Threat Flexibility results in the lowest reliability (0.05). The highest reliability (0.86) is obtained by teams with a low score on spread in Threat Flexibility and a high spread in HRO propensity.

H2-9c: The higher the variance in Team Orientation, the higher the reliability

The hypothesis cannot be validated significantly at the one-way ANOVA level. On the level of two-way ANOVA however, some conclusions can be drawn. For instance, the combination of a high variance in Team Orientation and a high degree of Sensitivity to Operations yields the worst reliability (-0.20). A low spread in Team Orientation combined with a high degree of Sensitivity to Operations yields the best reliability (0.86).

A high variance in Team Orientation and a high degree of Team Orientation yields the lowest reliability (-0.37) and the highest reliability (0.85) for the combination of a high degree of Team Orientation and a low spread in Team Orientation.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DSSupRes	DSTO	0,09	0,89	0,96	0,97	0,54	0,44
NPP	Non-Urgent	DN0pe	DSTO	0,08	0,77	-0,26	0,65	0,75	1,03
NPP	Non-Urgent	DMSO	DSTO	0,08	0,60	0,69	0,86	-0,20	1,06

NPP	Non-Urgent	DMTO	DSTO	0,04	0,57	0,68	0,85	-0,37	1,22
NPP	Non-Urgent	DS71	DSTO	0,05	0,63	-0,53	0,82	0,80	1,35
NPP	Non-Urgent	DM1	DSTO	0,06	0,69	0,41	0,91	-1,55	2,47
NPP	Non-Urgent	DS1	DSTO	0,06	0,69	0,41	0,91	-1,55	2,47

Table 6.64 - Variance in Two-way ANOVA for Team Orientation

H2-9d: The higher the variance in Threat Flexibility, the higher the reliability

On the one-way ANOVA level we have found no evidence for this hypothesis at an acceptable significant. At the two-way ANOVA level we have found support for this hypothesis in combination with a high degree for the number of urgent incidents per employee. A low spread in Threat Flexibility in combination with a low average number of urgent incidents per employ yields a high reliability as well (0.96).

For the handling of urgent incidents a low spread in Threat Flexibility yields the highest results when seen in combination with a low degree of several constructs (average number of urgent incidents per employee 0.96; degree of face-to-face communication 0.96 and spread in face-to-face communication 0.96; degree of supplementary resources 0.96)

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DN0pe	DSTF	0,08	0,96	0,51	0,90	0,97	0,46
NPP	Urgent	DMFac	DSTF	0,07	0,96	0,47	0,89	0,94	0,49
NPP	Urgent	DMSupRes	DSTF	0,06	0,96	0,46	0,89	0,94	0,49
NPP	Urgent	DSFac	DSTF	0,08	0,96	0,42	0,89	0,92	0,54
NPP	Non-Urgent	DSHRT	DSTF	0,09	0,40	0,80	0,86	0,05	0,81
NPP	Non-Urgent	DSSO	DSTF	0,06	0,39	0,86	0,87	0,01	0,86
NPP	Non-Urgent	DSOther	DSTF	0,07	0,73	-0,11	0,45	0,84	0,95
NPP	Non-Urgent	DMTO	DSTF	0,06	0,45	0,84	0,78	-0,11	0,96
NPP	Non-Urgent	DSDed	DSTF	0,08	0,44	0,92	0,89	-0,12	1,04

Table 6.65 - Two-way ANOVA for Spread in Threat Flexibility

H2-9e: The higher the variance in Preoccupation with Failure, the higher the reliability

This hypothesis could not be validated at an acceptable level of significance at the one-way ANOVA level. For urgent incidents, a high variance in Preoccupation with Failure only yields a high reliability (0.93) when combined with a high variance in the way teams deviate from procedure. The way teams deviate from procedure is much more homogeneous, reliability is the lowest (0.64). The highest reliability (0.96) is obtained with a combination of a low variance in Preoccupation with Failure and a low variance in the way teams deviate from procedure.

In combination with Team Orientation, the highest reliability (0.93) is obtained with low Team Orientation and a high variance in Preoccupation with Failure. The lowest reliability (0.03) with a high degree of Team Orientation and a high variance in Preoccupation with Failure.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DSPF	DS243INV	0,11	0,96	0,73	0,64	0,93	0,32
NPP	Non-Urgent	DSPF	DSSO	0,07	0,37	0,81	0,90	0,05	0,85
NPP	Non-Urgent	DMTO	DSPF	0,09	0,45	0,93	0,76	0,03	0,90
NPP	Non-Urgent	DSOther	DSPF	0,06	0,74	0,00	0,42	0,96	0,96
NPP	Non-Urgent	DM112	DSPF	0,11	0,58	-0,11	0,52	0,92	1,03

Table 6.66 - Two-way ANOVA for combinations of Preoccupation with Failure

H2-9f: The higher the variance in Sensitivity to Operations, the higher the reliability

The lowest reliability is obtained with a combination of high variance in the degree of Sensitivity to Operations and a high variance in Threat Flexibility.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Non-Urgent	DSSO	DSTF	0,06	0,39	0,86	0,87	0,01	0,86
NPP	Non-Urgent	DMHRT	DSSO	0,10	0,45	0,90	0,86	0,10	0,79
NPP	Non-Urgent	DSPF	DSSO	0,07	0,37	0,81	0,90	0,05	0,85
NPP	Non-Urgent	DSOther	DSSO	0,10	0,74	0,00	0,48	0,88	0,88
NPP	Non-Urgent	DMTeamSize	DSSO	0,06	0,48	0,86	0,80	-0,12	0,98
NPP	Non-Urgent	DN123pe	DSSO	0,10	0,64	-0,23	0,52	0,79	1,02
NPP	Non-Urgent	DM32	DSSO	0,02	0,43	0,85	0,81	-0,31	1,15
NPP	Non-Urgent	DS32	DSSO	0,01	0,80	-0,50	0,38	0,80	1,30
NPP	Non-Urgent	DNApe	DSSO	0,05	0,60	-0,51	0,57	0,81	1,31
NPP	Non-Urgent	DN0pe	DSSO	0,03	0,63	-0,51	0,50	0,81	1,31

Table 6.67 - Two-way ANOVA for variance in Sensitivity to Operations

H2-9g: The higher the variance in Deference to Expertise, the higher the reliability.

Case	*Type*	*Fact1*	*Fact2*	*Sig.*	*LL*	*LH*	*HL*	*HH*	*Spread*
NPP	Urgent	DMSeMa	DSDE	0,10	0,87	0,93	0,94	0,52	0,43
NPP	Urgent	DM32	DSDE	0,10	0,89	0,98	0,96	0,54	0,43
NPP	Urgent	DM31	DSDE	0,10	0,96	0,53	0,90	0,99	0,46
NPP	Urgent	DN0pe	DSDE	0,05	0,93	0,46	0,88	0,97	0,52
NPP	Urgent	DS9	DSDE	0,04	0,86	0,99	0,96	0,45	0,53
NPP	Non-Urgent	DMOther	DSDE	0,08	0,10	0,89	0,79	0,33	0,79
NPP	Non-Urgent	DS9	DSDE	0,06	0,07	0,90	0,71	0,15	0,83
NPP	Non-Urgent	DMScheme	DSDE	0,06	0,00	0,83	0,59	0,03	0,83
NPP	Non-Urgent	DMSeMa	DSDE	0,02	-0,10	0,87	0,74	0,13	0,97
NPP	Non-Urgent	DSScheme	DSDE	0,06	0,01	0,84	0,77	0,29	0,83

Table 6.68 - Two-way ANOVA for variance in Deference to Expertise

This hypothesis cannot be validated at the one-way ANOVA level at an acceptable level of significance.

At the two-way ANOVA level, a number of interactions catch our attention.

For the handling of urgent incidents, the average number of urgent incidents per employee strongly affects the process reliability. The highest reliability (0.97) is achieved for a high spread in Deference to Expertise, when employees have an on average high number of incidents to handle. But the combination of a low average number of urgent incidents per employee and a low spread in Deference to Expertise yields a high reliability as well (0.93)

A combination of a low score on SenseMaking properties and a low score on variance in Deference to Expertise yields the lowest reliability (Other 0.10; Scheme 0.00; SenseMaking in general -0.10). The highest reliability is obtained for a low score on these constructs in combination with a high spread in Deference to Expertise (Other 0.89; Scheme 0.83; SenseMaking in general 0.87).

Proposition 2-10

H2-10a: Teams that perceive Threat Flexibility more homogenously perform better than teams that do not.

This hypothesis could not be validated at an acceptable level of significance.

H2-10b: Teams that perceive efficiency drivenness more homogenously perform better than teams that do not.

This hypothesis could not be validated at an acceptable level of significance.

Propostion 2-11

Proposition 2-11: The better the fit between SeMa propensity and variety, the higher the reliability.

H2-11: More Eperienced teams, relying more on SeMa propensity, are more reliable.

This hypothesis could not be validated at an acceptable level of significance.

Chapter 7 Discussion

The dose makes the poison
Paracelsus (1493-1541)

This chapter discusses the research findings presented in the previous chapter. It successively addresses the findings from the inter-case comparison (Section 1) and the intra-case evaluation (Section 2).

1 Comparison of the Bank Case and the NPP Case [RQ1]

In this Section, we discuss how the HRO and SeMa characteristics of the two cases relate to each other. As we build on the findings from the data analysis, this chapter has an analogous outline as the previous chapter.

Proposition 1-1

Proposition 1-1: HRO properties are not unique, but HRO propensity levels are.

H1-1: HRO properties will be discernible in the archetypical HRO (NPP) as well as in the mainstream High Reliability Seeking organization (Bank).

This proposition can be supported for both cases since an exploratory factor analysis describes constructs with sufficient internal consistency that match the constructs described in HRT literature from 1999 onwards. That date is important because of the seminal paper by Weick, Sutcliffe and Obstfeld's (1999) in which they set the pace for future research on high reliability by introducing the five HRO constructs described in Chapter 2. Data show that of these five constructs, three constructs are discernable with sufficient internal validity: Preoccupation with Failure, Sensitivity to Operations and Deference to Expertise. Only the constructs of Reluctance to Simplify and Commitment to Resilience cannot be supported. However, with the three constructs, the Mindfulness criterion proposed by Weick et al. (1999) is covered, as can be seen from Figure 7.1 (Muhren et al., 2007, p. 579).

The fact that we have found the constructs in itself merely means that our questionnaire managed to measure the constructs under study. It not necessarily indicates that the organization under study is an HRO. However, since an exploratory factor analysis has found the same factors (constructs) in both cases, we can conclude that HRO constructs indeed are present in both cases.

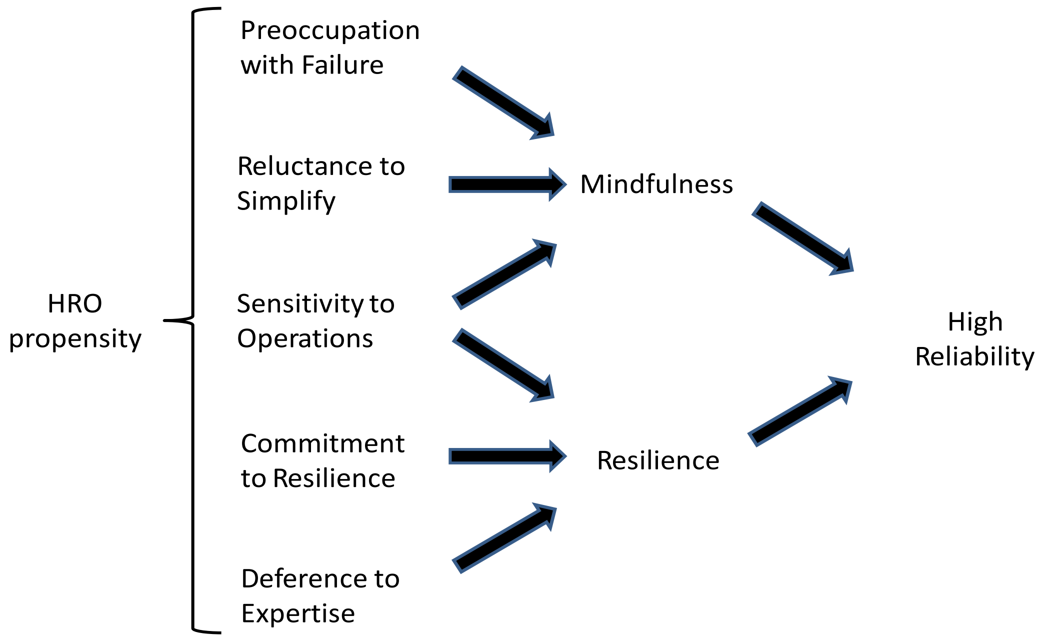

Figure 7.1 - Mindfulness (Adapted from Muhren, Van Den Eede, & Van de Walle 2007, p. 579)

Our research findings challenge, the construct taxonomy and description adopted in HRO research since 1999. Their high face-validity has added greatly to the popularity of the HRO domain as a discipline, both in academia and in practice. It has tremendous merit in stimulating thinking on what constitutes high reliability and through *Managing the Unexpected* (Weick & Sutcliffe, 2001) it has caught the attention of practitioners in the broader field of High Reliability Seeking Organizations (Vogus & Sutcliffe, 2007) as well. However, based on our findings we feel that a reconceptualization of the five classic high reliability constructs is imperative. We refer to our review of literature (Chapter 2) and posit that after the phase of diverging theorizing on High Reliability prior to 1999 and the phase of converging theorizing post 1999, time has come for research to formulate a synthesis of the two schools of thought. In accordance with our research methodology (Chapter 3) we bridge the characteristics of the Berkeley School (and its long-established constructs stemming from organization science) and the Michigan School (and its high face-valid constructs stemming from an accumulated insight into the high reliability domain).

The constructs that have emerged from our research seem to be capable of bridging the two schools of thought. Notably, Team Orientation, Threat Flexibility and Efficiency have that potential because they are capable of explaining what makes teams (or organizations) highly reliable and because they join in with constructs and research lines from mainstream organization science, as described in the reconceptualization exercise (Chapter 4). Complemented with constructs from the Michigan School, namely Preoccupation with Failure, Sensitivity to Operations and Deference to Expertise, this provides an interesting way of studying reliability. In both cases the presupposed construct of Commitment to Resilience and Reluctance to Simplify are not distinguished by a factor analysis. We feel this is not surprising because of the lack of univocality of these constructs. Reluctance to Simplify stands midway between Sensitivity to Operations and Preoccupation with Failure (Figure 7.1). With the former the construct shares its inherent modesty ‘to know that they do not know’ paving the way for *seeing* the *unseeable* and its focus on even the smallest error as a sign that something could be wrong with the system. With the latter it shares its focus on keeping an overview of the 'Swiss Cheese' (Reason, 1997). At the bottom end of the HRO construct spectrum, Commitment to Resilience stands midway between Sensitivity to Operations and Deference to Expertise. With the former the constructs shares its willingness to look and operate beyond the boundaries of one's own job description and management commitment to free up resources whenever necessary in order to cope with the unexpected. For the latter it paves the way for decision-making authority to be shifted down to the lowest possible levels. The mutual exclusiveness therefore cannot be guaranteed[70].

Hence, our conclusion that the Michigan school constructs are valuable but that their mutual exclusiveness does not hold. These constructs have proven to be advantageous for the prima facie development of HRT as a discipline, but can be considered detrimental in view of reaching maturity.

Proposition 1-2

Proposition 1-2: The non-archetypical HRO (the Bank) exhibits the same HRO characteristics as the archetypical HRO (the NPP) but to a lesser extent.

Recall from Chapter 5 that this implies the following hypotheses.

H1-2a: The average HRO propensity at the Bank is lower than at the NPP

H1-2b: The average Team Orientation at the Bank is lower than at the NPP

H1-2c: The average Threat Flexibility at the Bank is lower than at the NPP

H1-2d: The average Preoccupation with Failure at the Bank is lower than at the NPP

H1-2e: The average Sensitivity to Operations at the Bank is lower than at the NPP

H1-2f: The average Deference to Expertise at the Bank is lower than at the NPP

H1-2a: The average HRO propensity at the Bank is lower than at the NPP

This hypothesis is validated. The standard deviation in the NPP is considerably higher though than in the Bank. This observation is in line with what is suggested by theory, namely that an archetype like the NPP is more reliable than the Bank as a HRSO. However, the difference is relatively small. This leads us to comment on this finding in the event of a generalization. Based on this relatively small difference between the two organization types, and based on our action research, we feel that the HRO character of a HRSO is manifest. Notably from the interviews, we recall that the HRO propensity of the Bank was even more obvious than the HRO-likeness of the NPP. One explanation could be that we suffered from a researcher bias, instigated by the surprise of finding clear indications of genuine HRO traits. Another explanation could be that the items used in the survey were unalloyed HRO characteristics, stemming from a HRO jargon. This set of principles and jargon is more familiar to NPP staff than it is the incident handlers at the Bank. The HRO likeness of the Bank is much more difficult to seize in the known HRO jargon.

Apart from being less focused on safety, it is much more novel and revealing. Also in the Bank, "*although the human mortality rate is low, the risk of small failures amplifying into organizational mortality is high*" (Vogus & Welbourne, 2003a, p. 877).

H1-2b: The average Team Orientation at the Bank is lower than at the NPP

This hypothesis is validated. This could be explained by the structural effect revisions have on teams. Revisions are the yearly scheduled periods where a reactor is completely dismantled for maintenance purposes (For an elaboration see the NPP Case Description section in Chapter 3). The rhythm of the revisions is a pace that is felt throughout the plant's organization (Smals, 2006, p. 36). Apart from the stress during revisions and the relative periods of calm between them and the implications they have for the employees, this tidal system also has a very direct effect on team cohesion, interrelation and interaction. During revisions, maintenance teams work long hours and have crammed schedules for the entire length of the revision, which can last up to about six weeks. In these periods, workers are continuously in very close contact with each other, especially within individual teams. This strengthens the bonds between team members and builds very strong social structures. As one executive noted during an interview: "*[…] these men go through war four times a year*". This comparison may seem a bit exaggerated, but indeed, the loyalty that team members have for each other and the strong cohesion within teams may not be very different in nature from the social structures found in army battalions (Smals, 2006, p. 36). This observation was felt to a lesser extent only during our field observations in the Bank. The absence of activities that are comparable to the NPP's revisions can be seen as an explanation. The moments of tight-coupling are much rarer in the Bank context than in a NPP setting (Perrow, 1999).

H1-2c: The average Threat Flexibility at the Bank is lower than at the NPP

This hypothesis could not be validated, but the difference is only marginal. This is surprising in one way, because we had an a priori belief that a NPP, as an HRO archetype, would show a higher score on this exponent of resilience. The development of knowledge and skills to cope with and respond to errors, capability for swift feedback and swift learning, speed and accuracy in communications, flexible role structures, quick size-ups, experiential variety, skills at re-combining existing response repertoires, and comfort with improvisation (Weick & Sutcliffe, 2001, p. 67-68), are in line with the elasticity (van Fenema, 2005) associated with Threat Flexibility. Since Sutcliffe and Vogus (2003) suggest that resilience emerges from Threat Flexibility, and that resilience is omnipresent in a NPP, Threat Flexibility should be clearly observable as well. On the other hand, this observation may not come as a surprise. We point out three reasons: First, a NPP is also an archetype of an organization that is driven by procedure and where deviation from procedure is considered a capital error. This characteristic overrides Threat Flexibility traits because it leaves no room for degrees of freedom. Second, Threat Flexibility presupposes that information and resources are plenty available and that control is not tightened in up-tempo times. The NPP we have studied does the opposite. Thirdly and finally, it can be argued that a NPP is not a genuine HRO archetype but a URO (Chapter 4). Like the plants senior manager and several other interviewees repeatedly said to us: '*in case of doubt, there is no doubt*', meaning that they adopt an ultraconservative position towards the plant's safety. The position that NPPs are not HROs is a bit provoking maybe, but we feel

Amalberti et al. (2005) are right when they put NPPs outside of the set of HROs and position them under the set of *ultra-safe* organizations. Drawing on Amalberti and colleagues (2005) and their research in the context of safety in health care as a starting point, we label this organization typology a URO, an Ultra Reliable Organization. Keeping in mind what we have said on the relation between safety and reliability (Chapter 1), we can translate this framework into a new framework that changes the angle of safety for the angle of reliability. The result is the characterization of a new type of reliable organization, which we label 'Ultra Reliable Organization', or under its acronym URO.

The arguments for the discrimination between HRO and URO are important and are concentrated around the premise of *safety first*, with the quality of work preserved against unacceptable pressure (URO) instead of *production first*, with the degree of safety as high as possible for the imposed level of reliability (HRO). Regarding the stability of the process, a URO is determined by a well-codified and delineated area of expertise and ultra-dominant, rule-based behavior. A HRO on the other hand, is determined by a broad area of expertise and frequent knowledge-based behavior. The process reliability, in terms of risk per exposure, is better than 1 x 10^{-5}, possibly 1 x 10^{-6} for the URO and better than 1 x 10^{-4} for an HRO (Amalberti et al., 2005, p. 762).

In our view, however, the above categorization does not mean that High Reliability Organizations are inferior to Ultra Reliable Organizations. In fact, we argue the opposite: HROs are *better* than UROs. The context in which HROs have to perform is much more tiring than is the case of the UROs. But then again, also being Ultra Reliable is not an achievement either. It is only that the measures that have to be taken to guarantee this level of reliability are different as regards scope, intensity and level of application.

H1-2d: The average Preoccupation with Failure at the Bank is lower than at the NPP

This hypothesis is validated. Before the installment of a culture of collective mindfulness, the odds are that staff and management will deny the possibility of an unexpected event with disastrous consequences, or at least they will rationalize away the potential consequences (Weick & Sutcliffe, 2001, p. 92). As people implicitly become more conscious about the ways in which the system can be disrupted, what might go wrong, and who these disruptions are likely to harm, mindfulness increases (Weick & Sutcliffe, 2001, p. 92). Because of this increase in mindfulness, organization members now will explicitly accept that the unexpected *can* happen, or even that it *will* happen. In addition, such explicitism will reinforce consciousness considerably. From the qualitative part of our research (Chapter 3), we have learned that such an attitude was more manifest in the NPP than in the Bank. The NPP expects bad things to happen, whereas the Bank expects a normal course of events. The system dynamics effect just described therefore is reinforced in the NPP, more than it does in the Bank, and the result is a strong awareness that they are dealing with something out of the ordinary. In several interviews with NPP staff, we heard the same saying repeatedly: '*We are not a cookie factory*'.

The NPP has several mechanisms in place to safeguard this Preoccupation with Failure. One of them being the extensive training sessions on the simulator for teams from the operations department or improvised incident handling for teams from the maintenance department. From a social-constructionist perspective on learning (Kolb, 1976), it is not necessarily the empiric experience that triggers the learning, but somewhere in the process it is activated (Figure 7.2). A specific experience is needed for learning. The remarkable thing in HROs is that there is not necessarily such an experience and that – still – learning does take place. The organization (members) learn(s) from the non-event and give(s) it the status of an event. At best, it are small incidents or near misses, at worst, it are merely hypothetical ones, like in a simulation exercise.[71] HRO staff have developed multiple learning styles, hence their capacity to start learning at nearly every phase of the learning cycle depicted in Figure 7.2. Anyway, it will be clear that this is not an automatism and that a long-term continuing of such an effort should not be taken for granted. Paradoxically, in this respect an HRO's success becomes its major enemy (Miller, 1993).

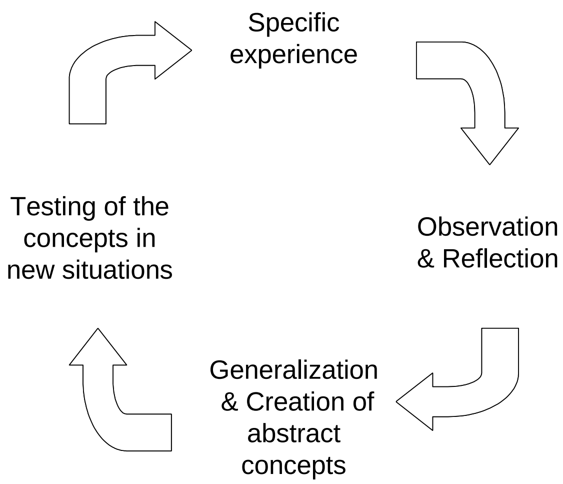

Figure 7.2 - Learning Cycle (Kolb 1976)

H1-2e: The average Sensitivity to Operations at the Bank is lower than at the NPP

This hypothesis is validated. Staff at the NPP, more than at the Bank, were constantly wondering *when*, *where*, *what* and *why* something was happening. They constantly were developing and adjusting their 'big picture'. The system of ex-ante incident reporting is far more developed than at the Bank, so that this well-developed situational awareness manages to deal with errors when they are still tractable and can still be isolated. When confronted with the Swiss Cheese model (Reason, 1997) interviewees recognized and appreciated this framework more than their Bank counterparts. The activity of constantly trying to find out where the holes are located in the cheese is more manifest in the NPP than in the Bank. Quoting Weick et al. (1999, p. 92-93): "*One byproduct of this increased attentiveness to all failures is that in contrast to their inconsequential role in traditional organizations, maintenance departments in HROs become central locations for organizational learning […]. Maintenance people come into contact with the largest number of failures, at earlier stages of development, and have an ongoing sense of vulnerabilities in the technology, sloppiness in the operations, gaps in the procedures, and sequences by which one error triggers another. These observations enlarge the database for learning and are given detailed attention*". This is what gives the NPP predictability and efficiency, but this also what gives it its rigidity and crudeness.

H1-2f: The average Deference to Expertise at the Bank is lower than at the NPP

This hypothesis is validated. Deference to Expertise is reported as a NPP hallmark (Bourrier, 1996). The flexibility and adaptability of a NPP assures that any problem can rapidly receive the attention it requires at all levels of the organization (Bourrier, 1996, p. 109). What we have learned in the field from our (in-real time and in person) witnessing a quite serious incident, is that errors are inevitable. The main characteristic of HROs is not that they are error-free, but that errors do not disable them (Bellamy et al., 2005;Weick & Sutcliffe, 2001). Deference to Expertise is an alternative formulation of the capacity of behavioral *discretion*, which is one of the causes of coupling (Orton & Weick, 1990). Behavioral discretion relates to the capacity for autonomous action (Orton & Weick, 1990, p. 210). This behavioral discretion is not observable during the NPP's normal operation, but becomes manifest during up-tempo events like the incident we have witnessed.

What people in HROs have mastered is the ability to alter typical hierarchical patterns of deference when the tempo of operations changes and unexpected problems arise. Decisions are then made on the front line by people who have the most expertise, regardless of their rank. In these situations, expertise and experience are usually more important than rank, so the decision structure in HROs is a hybrid of hierarchy and specialization. Decision-making authority therefore is shifted down to the lowest possible levels and clear lines of responsibility need to be called into existence (Ericksen & Dyer, 2005, p. 29). This way, the shift to anarchy is a controlled one, and comes from a collective, cultural belief that the necessary capabilities lie somewhere in the system and that migrating problems will find them (Muhren et al., 2007). The system is designed "*to oscillate effectively between various preplanned solutions to the more predictable aspects of a disaster circumstance and improvised approaches for the unforeseen and novel complications that often arise in such situations*" (Bigley & Roberts, 2001, p. 1282).

Proposition 1-3

Proposition 1-3: The higher the requisite variety of a team, the higher its HRO propensity

H1-3a: Teams using richer media exhibit a higher HRO propensity.

In the Bank Case, no proof found for validation/falsification of this hypothesis neither at the one-dimensional level, nor for the urgent, or for the non-urgent incidents. In the NPP Case, this hypothesis can be validated for non-urgent incidents only. Teams that show a diverse use of telephone in the handling of incidents (in general) achieve a higher reliability than teams that have the same tendency (regardless of the kind of inclination, positive or negative) towards the reliance on telephone. This finding challenges the hypothesis put forward by research on media richness (Daft & Lengel, 1986;Dennis, Fuller, & Valacich, 2008) and is in line with our findings from a case study in ongoing crisis situations (Muhren et al., 2009) that adds more nuance to the debate. H1-3a: Teams using richer media exhibit a higher HRO propensity. For instance, teams that rely more on face-to-face communication exhibit a higher HRO propensity. Drilling down to the level of the HRT sub-constructs, we see that especially Deference to Expertise and Sensitivity to Operations are accountable for this observation. Richer media offer more occasions for discovering subtle clues that might lead to a solution for the incident.

Waterman (1990) reports on team composition as an area often overlooked. He argues that membership of teams is crucial in their success: when membership is too homogeneous, reliability usually suffers. Studies in which very bright experts comprise a team, have been shown to underperform due to competition, abstractness, and individual rather than Team Orientation by members. Some of the considerations offered by Waterman are (1) to make sure styles are diverse and complementary. Diverse styles ensure that all perspectives on a problem are covered and different skills are brought to bear at stages of problem solving. However, greater diversity requires more time to be spent on acquaintance, team building, and conflict resolution; (2) that members should have relevant and diverse skills; (3) to get experienced team players or develop them.[72]

H1-3b: More experienced teams exhibit a higher HRO propensity.

For the Bank Case, this hypothesis cannot be validated for the HRT construct as a whole but, data show allow for conclusions at an acceptable level of significance for four constructs: Preoccupation with Failure and Deference to Expertise and for Threat Flexibility and Logics of Action. Regarding Preoccupation with Failure, it can be derived that more experienced teams are showing a higher score in this construct than less experienced ones. This might be because these teams have experienced more things going wrong than teams with less experience in the field. On the other hand, less experienced teams show a higher degree of Deference to Expertise than more experienced ones. This observation that less experienced teams exhibit a higher score on Deference to Expertise constructs, could be explained by a *drive* among younger staff members and a higher intrinsic motivation to achieve and to conform to the image of the ideal employee. It can be presupposed that the need to be self-efficacious is greater among less experienced, and on balance younger, staff. The same goes for the construct Logics of Action. Recalling the underlying items, more particularly regarding the perception of being sufficiently trained and experienced (survey item 22.4) and having a sufficient degree of freedom for doing the job (survey item 22.2), we can argue that that same drive accounts for this observation. A plausible explanation for the fact that less experienced teams exhibit a high score on the construct of Logic of action regarding the third construct item, namely the number of informal contacts within the organization to solve problems (13.6) could be that teams with little experience value an informal network more than people with more experience. Together with the gaining of experience, the need for developing an informal network decreases. The effect thereof is faded by the two other items. These findings seem to indicate that being HRO-like is a lifetime achievement and that there must be moderating variables that come into play.

For the NPP Case, this hypothesis cannot be validated at an acceptable level of significance. This suggests that experience has no statistically significant impact on HRO propensity. This can be explained through a homogenizing effect of working at a NPP, which is driven by this one common interest of '*safety first*' (Smals, 2006). Not a single occasion to emphasize the necessity for sufficient attention to the safety aspects of one's work is missed. In situations where a choice must be made between giving priority to production or avoiding any unnecessary risks, safety aspects *always* put more weight in the scale (Schulman, 1993a;1993b;La Porte & Consolini, 1991;Creed et al., 1993). Decisions on lower hierarchical levels that place safety above efficiency of operations are never disputed by higher management or peers of the decision maker. Indeed, the demand to work in the securest possible way is perhaps one of the most apparent aspects of the plant's organizational culture and it permeates through the entire organization. When planning jobs that involve exposure of personnel to radiation, a principle is applied that urges planners to keep doses as low as possible: ALARA, which stands for As Low As Reasonably Achievable (Prasad, Cole, & Haase, 2004), a principle that is well-known in every industry where people come into (indirect) contact with radioactive substances (Smals, 2006, p. 35).

Proposition 1-4

Proposition 1-4: The higher the requisite variety of a team, the higher its SenseMaking propensity

H1-4a: Teams using richer media exhibit a higher SenseMaking propensity.

In the Bank Case, this hypothesis cannot be validated overall. Yet it is validated for the SeMa sub-construct *Self*. A similar observation can be made in the NPP Case where although the hypothesis cannot be validated at an acceptable level of significance, drilling down to the level of the SeMa sub-construct *Other* is validating the hypothesis. The different observation in the Bank and in the NPP is interesting. First, the correlation between Self and media richness in the Bank Case is revelatory because it suggests the importance of the way people construct identity for the design and use of communication systems. From the perspective of SenseMaking, who we think we are (identity) as organizational actors lies primarily in the hands of others: "*How can I know who we are becoming until I see what they say and do with our actions?*" (Weick et al., 2005, p. 416). Notably the degree of emotional involvement with the job and the sense of honor in doing the job right is an important factor with respect to media richness. People create their reality by making decisions based on what they observe and who they are. Teams that have a higher propensity to Identity Constructing do rely more on rich media for their communication. Second, the correlation between Other and media richness in the NPP Case is quite startling as well because it suggests the importance of the way people work together towards a common goal. Other people are integral to our efforts to make sense of things because what we say, think, or do is contingent on what others say, think, and do. People learn about events when they compare what they see with what someone else sees and then negotiate some mutually acceptable version of what really happened (Weick, 1985). Our data show that staff at the NPP has a preference towards using rich media for this aspect of SenseMaking. The interpretation we give to this finding is that it is a consequence of the NPP's strong score on Team Orientation. They are two sides of the same coin.

These findings have implications for the way communication systems are designed and implemented at the Bank and the NPP. The question arises in which way this correlation induces causality. If there is causality, is it that the SeMa propensity influences the media preference, or is it that the preference for a certain type of media leads to a certain degree of SeMa propensity? The design of this study does not permit us to pronounce upon this question. However, we can refer to a field survey we have conducted in the Democratic Republic of Congo (Muhren et al., 2009), studying the relevance of SenseMaking for communication. Analyzing communication and SenseMaking data obtained from in-depth interviews shows that humanitarian actors in the DRC engage in eight different SenseMaking communication activities: noticing, updating, inquiring, triangulating, verifying, reflecting, enacting, and interpreting. Throughout our analysis, we have studied SenseMaking at the level where the goal of communication is to reach individual understanding rather than shared understanding. We have also observed that the communication process does not start with the sending of a message, but incorporates making sense of the situation. Studying communication processes from a SenseMaking angle therefore provides a more holistic view of the communication process. Our findings also show that social interaction and enactment are vital for actors in the DRC to reach individual understanding, and that low synchronicity media will not provide for the best support in achieving this. Instead, actors will rather need high synchronicity media for these conveyance processes. Because of the continuous needs of building a SenseMaking communication infrastructure, designers of Information and Communication Systems (ICS) should allow users to connect. In contrast to how most of the ICS are designed and developed, they should not solely focus on institutional information and communication exchanges, but support exchanges in these mostly informal, personal based networks. The scanning media example of social networking software will for instance enable humanitarian actors to create and maintain their important network of contacts.

H1-4b: More experienced teams exhibit a higher SeMa propensity.

In the Bank Case, we found no proof for this assertion for the SeMa root construct, but when drilling down to the level of the sub-constructs a falsification for the hypothesis could be provided. Teams with a lower score on Scheme, are more experienced on average than teams exhibiting a higher score on Scheme. We recall from the reconceptualization chapter (Chapter 4), that a Scheme is a mental structure people rely on to organize information they come across, based on previous experiences and suitable for present and future SenseMaking (Ericson, 2001, p. 117;Graesser et al., 1979). The construct refers to the Retrospective, Enacting, Cue Extracting and Plausibility SenseMaking property. It represents one's understanding of the world by filling in white spots where information is missing (Gioia & Poole, 1984). The collection of cognitive schemes of people in a team or an organization is what is called its 'cognitive profile' (Ericson, 2001, p. 118). Several scheme-building methods are available. We categorize them as (1) decision making and (2) SenseMaking. The falsification of the hypothesis is remarkable and calls for further theorizing. It suggests that the more experienced a team is, the less it relies on what is plausible, but that they are more driven by accuracy and ratio. Prima facie, we have found this conclusion hard to explain, because we assumed that the higher the level of experience, the smaller the importance of ratio and accuracy, the smaller the reliance on DecisionMaking, the more intuitive work would become. However, more experienced teams have gained a much higher degree of confidence in their work that they rely on a sound set of heuristics, scenarios and short-cuts that have proved their value in the past. It can be assumed that such a set is gradually developed at a lower level of maturity – basically through SenseMaking – but that after its emergence this set has started to live a life on its own as on-the-shelf solutions for the majority of situations. The fact that less experienced teams exhibit more orientation towards SeMa is in line with this induction. Because of their lack of experience, they are confronted more with *gappiness* (Dervin, 1999) and need to make sense of situations. From the moment '*sense is made*', maturity is gained but time will have gone by so that their experience (expressed and measured as the number of years of experience in the job) will have increased as well. At the same time gaps are filled and replaced with (for instance) rules of thumb that have an aura of ratio and accuracy.

In the NPP Case, this hypothesis can be falsified. Teams with a lower level of experience perform better in the handling of urgent incidents. The fact that lower experience can lead to a higher level of reliability for urgent incidents possibly could be explained by a mental or physical fatigue. As an explanation, we refer to the notion of Hypervigilance (Janis, 1982a), addressed earlier in this discussion. This calls for urgent special action on the side of the NPP's management.

The above theorizing is done ceteris paribus, under stable conditions. However, when circumstances would change, the SenseMaking function would not necessarily be decreasing linearly. For instance, if the situation changes dramatically with 'the unexpected' happening, with ambiguity regarding cause and effect, a new phase of ambiguity (gappiness) would emerge. This increase in complexity would lead to a rather sudden increase of the SenseMaking propensity (and function) to the detriment of the DecisionMaking propensity. This is shown in Figure 7.3, with the *explosion* icons representing an unexpected event with a possible severe impact.

This sheds some light on the SenseMaking mechanism and makes the construct more nuanced. It would mean that SenseMaking propensity is not a static property, but evolves over time.

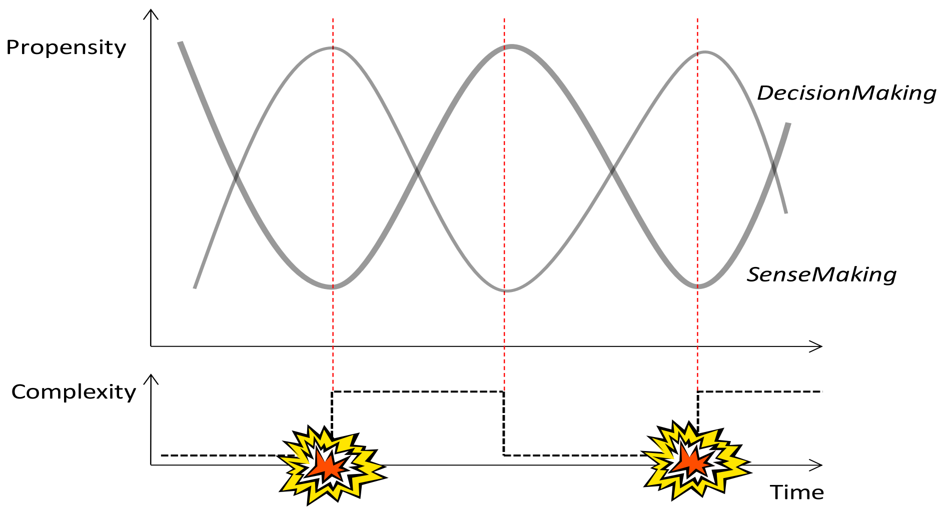

Figure 7.3 - The Evolution of SenseMaking Propensity

Proposition 1-5

Proposition 1-5: The non-archetypical HRO (the Bank) exhibits the same HRO characteristics as the archetypical HRO (the NPP) but with a lower variance.

Taking the standard deviation as a measure of this variance (spread), we come to the validation of the following hypotheses:

H1-5a: The variance in HRO propensity at the Bank is lower than at the NPP

H1-5b: The variance in Team Orientation at the Bank is lower than at the NPP

H1-5c: The variance in Threat Flexibility at the Bank is lower than at the NPP

H1-5d: The variance in Preoccupation with Failure at the Bank is lower than at the NPP

H1-5e: The variance in Sensitivity to Operations at the Bank is lower than at the NPP

These hypotheses are validated. Burke et al. (2005) notice that it is very unlikely that everyone in the HRO sees the big picture, because of the system's complexity. In line with what is suggested by NAT on the interactive complexity of the nuclear energy sector, this explains why the spread in Sensitivity to Operations in a NPP is higher than in a Bank.

H1-5f: The variance in Deference to Expertise at the Bank is lower than at the NPP

This hypothesis is validated. The higher variance for the NPP teams is not in line with what we would have expected at the start of our research, were literature review – at least implicitly – seemed to suggest that a homogenous HRO propensity was a characteristic of the archetypical HRO. However, from our field observations, interviews and system dynamics modeling exercises (See Chapter 3), we came to challenge this belief and questioned the HRO homogeneity of the NPP. The variance in HRO propensity can be seen as following the principle of requisite variety. As we have described in the Introduction chapter, organizations tend to simplify the complexity of their environment to the extreme and therefore seem to be caught in seeing homogeneity as a magic formula for success and consider team homogeneity as a management ideal. In order to cope with complexity, some requisite variety is necessary. Therefore, more divergence in an organization's HRO propensity, paradoxically enough, is stronger an indication of HRO propensity than less divergence. This is where HRO propensity and SenseMaking propensity meet. Indeed, also the need for SenseMaking is the consequence of the drift to simplify to the extreme. This simplification concerns both the way reality is observed and the way an organization tends to homogenize its constituent parts, including its people.

Proposition 1-6

Proposition 1-6: The non-archetypical HRO (the Bank) exhibits the same SeMa characteristics as the archetypical HRO (the NPP) but with a lower variance.

H1-6a: The variance in SenseMaking propensity at the Bank is lower than at the NPP

H1-6b: The variance in Self-propensity at the Bank is lower than at the NPP

H1-6c: The variance in Other propensity at the Bank is lower than at the NPP

H1-6d: The variance in Scheme propensity at the Bank is lower than at the NPP

H1- 6a: The variance in SenseMaking propensity at the Bank is lower than at the NPP

The hypothesis regarding the aggregated (root) SeMa construct is falsified. However, two out of three of its underlying sub-constructs can be validated.

H1-6b: The variance in Self propensity at the Bank is lower than at the NPP

This hypothesis is falsified.

H1-6c: The variance in Other propensity at the Bank is lower than at the NPP

This hypothesis is validated.

H1-6d: The variance in Scheme propensity at the Bank is lower than at the NPP

This hypothesis is validated.

The idea behind the proposition is that a low variance, i.e. a high degree of homogeneity is counter-indicative for high reliability, as well for the HRO propensity as for the SeMa propensity. In general, the findings for H1-1-6c and H1-1-6d therefore are in line with this supposition. The falsification regarding the Self construct (H1-1-6b) is also responsible for the falsification of the SeMa root construct (H1-1-6a). It can be explained as a NPP idiosyncrasy of taking an extreme pride in one’s job. For instance, the imposing technical plant facility, the direct link between the job and the education and training received, the macho culture (almost a 100% male working environment), the intensive training sessions or the employee of the month contest, are plausible explanations.

Proposition 1-7

Proposition 1-7: The constructs of Mindfulness and Resilience interrelate

H1-7a: The higher a team’s Preoccupation with Failure, the lower its Deference to Expertise.

We have not been able to validate this hypothesis in the Bank Case, whereas in the NPP Case it is falsified. This finding is in line with what is – at least implicitly – suggested by HRO scholars, namely that it is possible to be resilient and mindful at the same time. It is in line with the ex posteriori interpretation of the qualitative part of the research, where nor the outcomes of the interviews, nor the outcomes of the GSS workshops indicated that such combination would be impossible.

H1-7b: Mindfulness is a prerequisite for Resilience.

We have been able to validate this hypothesis for the Bank Case as teams with a low degree of Deference to Expertise exhibit a low score on Sensitivity to Operations. It has been impossible to validate the hypothesis for the NPP Case at an acceptable level of significance.

This indicates that it is possible to be simultaneously mindful and resilient. Interesting is the difference in observation between the constructs 'Sensitivity to Operations' – which is as we have shown in Figure 7.1 and as developed earlier in this discussion chapter an exponent of Resilience – and 'Preoccupation with Failure', as an exponent of Mindfulness. The notions of Mindfulness and Resilience introduce a paradox: Mindfulness is the enemy of resilience. An organization that tries to be mindful has a better chance of being stable in the long short because it avoids intrusions on its processes. The organization is not endangered and can continue to operate as it is used to; business as usual. An organization that tries to be resilient, on the other hand, has a better chance of being stable in the end because it has learnt how to deal with intrusions in its processes. We refer to the result of the interview with a head of a mainframe department in the Bank who pointed out the danger in becoming very successful in operating their mainframe infrastructure. The same story could be heard while interviewing personnel from the NPP who argued that younger staff did not have the experience the older staff has on dealing with the teething troubles of nuclear installations: "*The machinery is running smoothly, too smoothly*".

The relationship between Mindfulness and Resilience (Figure 7.1) is not univocal. It is fuzzy, but hence also more interesting and useful. Both constructs are like Siamese Twins: They cannot live with each other, but neither can they live without each other. Like in all cases where paradox arises, it is good to realize that paradox is essential in keeping "*the organization on its toes, in a state of continuous awareness of its own contradictions*".

Proposition 1-8

Proposition 1-8: The NPP is more reliable than the Bank

H1-8: The NPP is more reliable than the Bank

Based on the criterion of range (minimum vs. maximum value) for inter-case comparison of process reliability, we have found that the Bank is more reliable than the NPP regarding the overall handling of incidents, more reliable than the NPP with respect to the urgent incidents and less reliable than the NPP in the handling of non-urgent incidents.

The Bank's higher reliability is a remarkable observation. A priori, we would not have expected that a *garden variety* HRO would exhibit higher reliability, than an archetypical HRO like a NPP. We believe this situation can be explained in three ways. The first two reasons are technical, the last reason provides a more fundamental explanation.

First, the technique we have used is far from perfect because it uses range as a measure. Even though we have smoothed the extreme effect of range by calculating the average range, it still is not ideal as a measure for reliability. Second, the definition of what is urgent and non-urgent is quite different between our two cases. Time-horizons are much longer in the NPP compared to the Bank, whereas the level of complexity in the NPP is much greater than in the Bank (number of actors involved, safety issues, external regulations, etc.). This might explain in part this unexpected observation. Third, the observation that the Bank is more reliable (than the NPP) for the urgent incidents, does not come as a complete surprise. The Bank pays particular attention to the timely handling of urgent incidents. In order to meet deadlines, it has in place numerous procedures, roles, communication lines. Amongst others: (1) the morning briefings where all urgent incident of the past 24 hours are discussed; (2) the Service Delivery Owner who as a boundary spanner takes ownership of the incident and whose job it is to resolve the incident in the quickest possible time-frame; (3) publication of the incident status on the company intranet, creating a considerable visibility throughout the organization; (4) intense senior management commitment and personal follow-up to name just these. We refer to the case descriptions (Chapter 3, Section 2) for an elaboration of these measures. From interviews can be learned that the NPP, at the time we were studying it, had pointed out that the timely handling of its urgent (i.e. non-planable) Maintenance & Repair work was a major concern, whereas this was not reported upon as a problem with respect to the non-urgent work.

2 Measuring Reliability [RQ2]

In this Section, we discuss how organizational characteristics influence reliability. We do so for each proposition separately.

Proposition 2-1

Proposition 2-1 : The higher the HRO propensity, the higher the reliability.

H2-1a: Teams exhibiting a higher propensity towards Team Orientation yield better reliability in the handling of urgent incidents, whereas this is counterproductive for the handling of non-urgent incidents.

H2-1b: Teams exhibiting a high propensity towards Team Orientation and exhibiting a high degree of Sensitivity to Operations yield a higher reliability than teams than the same teams exhibiting a low degree of Sensitivity to Operations.

H2-1c: The higher the average Threat Flexibility, the higher the reliability.

H2-1d: Teams that operate in a less restrictive (more supportive) organizational climate perform better than teams that do not (Smith-Crowe, Burke, & Landis 2003).

H2-1e: Teams that operate in a less efficiency-driven (more slack) organizational climate perform better than teams that do not.

H2-1a: Teams exhibiting a higher propensity towards Team Orientation yield higher reliability in the handling of urgent incidents, whereas this is counterproductive for the handling of non-urgent incidents.

Neither for the Bank nor for the NPP Case, evidence can be been found for this hypothesis. Such could indicate that there is no one-dimensional effect of Team Orientation on reliability (positively nor negatively inclined). Other effects might play a role, as is shown by the two-way ANOVA that do lead to significant observations. In view of the all-in-all small number of units of analysis (n=37) this observation is remarkable, because if one were to expect significance it definitely would be for the one-way ANOVA and not for the two-way ANOVA. This is a strong indication for the thesis that based on existing literature there is no univocal formula for HRO success, but that contingency theory applies.

H2-1b: Teams with a high propensity towards Team Orientation and exhibiting a high degree of Sensitivity to Operations yield a higher reliability than the same teams exhibiting a low degree of Sensitivity to Operations.

Neither for the Bank nor for the Bank Case, have we found evidence for this hypothesis at an acceptable level of significance.

2-1c: The higher the average Threat Flexibility, the higher the reliability.

In the Bank Case we have falsified this hypothesis. For urgent incidents, a low average score on Threat Flexibility results in the highest reliability. At the NPP, the highest reliability is achieved by teams with a high score on Threat Flexibility in combination with a high score on SeMa and HRT constructs, regardless of the incident type. Remarkable in this respect is the observation that a low degree of Threat Flexibility in combination with a low score on SenseMaking and HRT constructs yields a high reliability as well. Combinations of a high degree on the constructs under study yield the highest reliability when they are directly proportional. Therefore, the conclusion should be that two strategies are worth considering: (1) high Threat Flexibility in combination with a high degree of SenseMaking propensity and with a high degree of HRO propensity.

H2-1d: Teams that operate in a less restrictive (more supportive) organizational climate perform better than teams that do not.

The construct covering the degree of supportiveness is Threat Flexibility.

For the Bank Case, we have found evidence for the falsification of this hypothesis, namely that where the handling of urgent incidents (threat) is concerned, a more restrictive (less supportive) degree of Threat Flexibility is positively influencing reliability, regardless of any mediating variable. We notice however that the spread between the highest and lowest expected average reliability is a little lower than the average spread. At this one-way ANOVA level, we have found no sufficient significance for the non-urgent incidents. For the NPP Case, we have found no significant proof for this hypothesis. Nor for the urgent incidents, nor for the non-urgent incidents, the degree of restrictiveness/supportiveness of Threat Flexibility is positively influencing reliability, regardless of any mediating variable.

This may indicate that Threat Rigidity is not necessarily a bad strategy after all, meaning that restriction of information, tightening of control, squeezing on the resources favors reliability in case of critical circumstances. This is challenging work by Sandelands et al (1981) and complements the Vogus and Welbourne (2003a) study on Threat Flexibility. A rationale behind this observation could be that the urgency of the incidents does not correspond to the characteristics of a threat: uncertainty, complexity, ambiguity, etc., and therefore, the mechanisms behind threat rigidity/Threat Flexibility would not apply. When the incident represents a situation that is known or knowable, then heuristics, algorithms and procedures will provide a valuable assistance in resolving them. In most urgent incidents this is the case. A restricted leadership style suits such situations better than one that is oriented towards Threat Flexibility. This puts the Threat Flexibility theme in a new light by making the necessary differentiations.

Especially in the archetypical context of an NPP where processes are procedure driven par excellence the Threat Flexibility construct is particularly interesting. During our interviews and observations, we were confronted at several occasions with the ambiguous attitude towards the degree of restrictiveness/supportiveness of Threat Flexibility. On the one hand, it could be heard that sticking to procedures is the *conditio sine qua non*, especially in situations under stress. On the other hand, it became obvious that the difference in Threat Flexibility in terms of restrictiveness/supportiveness has the potential of explaining organizational reliability as well. Supposedly, this ambiguous and equivocal position of the Threat Flexibility constructs explains why it shows no significant one-dimensional effect on organizational reliability. This suggests that a two-dimensional effect bears more promises for explaining the dependent variable.

Our findings are in line with Carley and Zhiang's (1995) findings that no coordination scheme – hierarchy or team, or put differently threat rigidity or Threat Flexibility – dominated. Their research outcome shows that teams outperform hierarchies when the task is unbiased but that hierarchies can outperform teams when the task is biased if they have the right information access structure and right level turnover. This strengthens our assertion that work in the NPP most of the time is not complex, but merely complicated (Bennet & Bennet, 2004), which is challenging Perrow's (1999) assertion that a NPP as a whole is an interactively complex enterprise. The conclusion therefore is that different coordination schemes are optimal for different tasks.

H2-1e: Teams that operate in a less efficiency-driven organizational climate perform better than teams that do not.

For the Bank as well as for the NPP, we have found evidence for the falsification of this hypothesis, concerning the handling of urgent incidents as well as the non-urgent incidents. Both for the Bank and for the NPP, a higher focus on efficiency is positively influencing reliability, regardless of any mediating variable. We notice however that the spread between the highest and lowest expected average reliability is a little lower than the average spread (but substantially lower for the non-urgent incidents.

This can be explained through the notion of ambidextrous organization (Tushman & O'Reilly, 1997). A so-called ambidextrous organization can operate in multiple modes simultaneously, managing for short-term efficiency by emphasizing stability and control, and for long-term innovation by taking risks and learning by doing (Tushman & O'Reilly, 1999). They are ambidextrous, hosting multiple, internally inconsistent architectures, competencies and cultures, with built-in capabilities for efficiency, consistency and reliability on the one hand, and experimentation, improvisation and luck on the other. "*They exhibit relatively formalized roles and responsibilities, centralized procedures, functional structures, efficiency-oriented cultures, highly engineered work processes, strong manufacturing and sales capabilities and relatively homogeneous, older and experienced human resources*" (Tushman & O'Reilly, 1999). These efficiency-oriented units have relatively short time frames and are often relatively large and old with highly ingrained, taken-for-granted assumptions and knowledge systems. Their cultures emphasize efficiency, teamwork and continuous improvement. From our findings, it can be supposed that the Bank's incident management is a process that bears all the hallmarks of one side of the ambidextrous organization.

For the NPP Case, we have found no evidence for any of the HRO constructs, meaning that we have not been able to validate this hypothesis. This is in line with the analysis for the Bank Case where there was no one-dimensional effect of HRO propensity on reliability (positively nor negatively inclined). Other effects might play a role. In view of the all-in-all small number of units of analysis (n=24) this observation is remarkable, because if one were to expect significance it definitely would be for the one-way ANOVA and not for the two-way ANOVA. This is a strong indication for the thesis that based on existing literature there is no univocal formula for HRO success, but that contingency theory applies. One of the objectives of this research is to shed some light on this contingency black box. We do so by examining the balance between effectiveness and efficiency. We deal with this issue next.

The triangulation between qualitative and quantitative techniques has yielded substantial additional insights into the nature of HROs. More particularly the insight that:

- the dose makes the poison;
- moderators have a tremendous impact;
- the effect of factors over time can alter;
- the composition of HRO constructs differs from what is suggested in literature;
- some constructs are incompatible;
- there is an undeniable relation between efficiency and effectiveness.

The economic dimension is essential in our approach of High Reliability Theorizing. In that sense, our view contrasts sharply with dominant HRO literature (Weick et al., 1999) which seems to suggest that mindfulness is 'costless' (Vogus & Welbourne, 2003a, p. 881). However, as pointed out by HRO researchers like La Porte (1996), Levinthal and Rerup (2006), and Rerup (2005), ongoing mindfulness comes at a cost. Among these scholars, Rerup (2005) has been the most vigorous in making the cost and benefit structure of Mindfulness explicit. In that sense he warns that too much Preoccupation with Failure paints too dark a picture of the situation. Besides, in pursuit of a blind attempt to minimize the chance of failure, unnecessary and costly adjustments to routines and practices that worked in the past can be the consequence. A Reluctance to Simplify interpretation (e.g. the diversity of opinion and multiple perspectives) may similarly generate too much discussion and too little action, as well as provoking unnecessary skepticism, preventing the business venture/economic exploitation of good ideas. Sensitivity to Operations can lead to cognitive overload. Commitment to Resilience can cause a hyper-response triggered by almost any one clue. If all events are seen as unexpected and important, in the end, nothing is. Therefore, it is wise to heed as well as to ignore some events and signals. Deference to Expertise, finally, may also generate 'noise,' creating cognitive overload (Rerup, 2005, p. 462).

Theoretically, the ideal degree of mindfulness can be determined and – if one would succeed in quantifying all the underlying variables and constants – one could determine it mathematically. This would be an exercise to be dealt with by means of quantitative system dynamics (see:

future research). We posit however, that regardless of a precise calculation of the optimal degree of mindfulness, successful HROs explicitly do take into account – if not all, then still most of – the constants and variable contributing to mindfulness. We refer to a workshop and conversation with the High Reliability Officers from British Petrolium (Colin Reid) and Shell (Ian Crawford) at the previous HRO conference (Stewart, 2000).

Proposition 2-2

Proposition 2-2 : The higher the SeMa propensity, the higher the reliability.

H2-2a: The higher the variance in SeMa propensity, the higher the reliability.

H2-2b: The higher the variance in Scheme, the higher the reliability.

H2-2c: The higher the variance in Ongoing, the higher the reliability.

H2-2a: The higher the variance in SeMa propensity, the higher the reliability

In the Bank Case, we have found no significance to support this hypothesis at the one-way ANOVA level, but at the two-way ANOVA level, a low spread in SenseMaking propensity yields the highest reliability. In the NPP Case, we have found no evidence for this assumption at the one-way ANOVA level. At the two-way level ANOVA however, this hypothesis can be falsified. In general, the higher the spread in SenseMaking, the lower the incident management reliability. More particularly, in the case of the handling of urgent incidents, a high homogenous degree of SenseMaking propensity leads to the highest reliability, whereas a high but heterogeneous degree of SenseMaking propensity leads to the lowest reliability. Univocal SenseMaking propensity seems to have a clear relevance for the composition of incident response teams

H2-2b: The higher the variance in Scheme, the higher the reliability

At the Bank, we have found no significance to support this hypothesis at the one-way ANOVA level, but at the two-way ANOVA level, a low spread in SenseMaking propensity yields the highest reliability. In the NPP, we have found no significant evidence for this hypothesis at the one-way ANOVA level. At the two-way ANOVA level we can falsify the hypothesis. A high variance in Scheme results in high reliability in combination with a low spread in the perception of the availability of Supplementary Resources or with a high variance in the perception of Pressure.

A low variance in Scheme results in high reliability in combination with a high or low spread in the perception of the availability of Supplementary Resources or with a high variance in the perception of Pressure.

H2-2c: The higher the variance in Ongoing, the higher the reliability

In the Bank Case, we have found no significance to support this hypothesis at the one-way ANOVA level, but at the two-way ANOVA level, a low spread in Enactment yields the highest reliability. In the NPP Case, this hypothesis can be validated at the two-way ANOVA level where the combination of larger teams and a more heterogeneous enactment results in the highest reliability whereas the combination of larger teams and a more homogenous enactment results in the lowest reliability.

Teams with more female members that exhibit more enactment properties are highly reliable whereas they are less reliable when they exhibit less enactment properties. More male teams are relatively indifferent towards the enactment properties.

Proposition 2-3

Proposition 2-3 : The lower the use of dedicated IS, the higher the reliability.

H2-3: Teams using richer media are more reliable.

Proposition 2-4

Proposition 2-4: The better the fit between HRO propensity and IS use, the higher the reliability.

H2-4a: Teams exhibiting a high propensity towards Team Orientation, relying on richer media will yield a better reliability.

H2-4b: Teams relying little on the dedicated IS and exhibiting a higher HRO propensity perform better than when they rely more on dedicated IS.

H2-4a: Teams exhibiting a high propensity towards Team Orientation, relying on richer media yield a higher reliability.

In the NPP Case, teams with a high degree of Team Orientation and a high degree of reliance on face-to-face communication yield the highest reliability in the handling of urgent incidents. This reliability is very high. When these teams rely little on face-to-face communication their reliability drops considerably. The reliability of teams with a smaller degree of Team Orientation is independent from the degree of reliance on face-to-face communication. That the hypothesis can be validated for urgent incidents can be explained by the fact that teams with a strong Team Orientation discuss situations on a frequent level. One might suppose that there is a mutual influence between both constructs. It can be assumed that teams with less orientation on the team have team members that may be close to each other, thus favoring face-to-face communication.

H2-4b: Teams relying little on the dedicated IS and exhibiting a higher HRO propensity perform better than when they rely more on the dedicated IS.

In the Bank Case, higher immediate incident registration in combination with a high homogeneity in HRO propensity results in the lowest reliability in the handling of urgent incidents. Lower immediate registration, in combination with a high homogeneity in HRO propensity, results in the highest reliability, more particularly regarding the homogeneity of the Deference to Expertise and Preoccupation with Failure constructs. Remarkable is that in case of non-urgent incidents, the same observation can be made regarding the Preoccupation with

Failure, but that at the same time also a high reliability is obtained for the combination of a high degree of variance with a high degree of immediate registration.

Also in the Bank, for urgent as well as non-urgent incidents, teams with a high homogeneity in incident management focus and a low reliance on the dedicated system for their communication yield the best reliability whereas they yield the worst reliability when they do rely more. For non-urgent incidents, a low proportion of time devoted to the handling of incidents in combination with a high degree of use of Peregrine yields the worst reliability, whereas in combination with a low reliance on Peregrine yields the best reliability.

At the NPP, teams whose management expects they rigorously stick to procedures and that homogenously rely on dedicated IS in the handling of incidents score the highest reliability in the handling of urgent incidents. When these teams are less homogenous in the way they rely on dedicated IS, their reliability drops considerably. This underlines the relevance of the hypothesis as a guideline for the design of information systems. Teams whose management allows team members to deviate more from procedure and that exhibit a high variance in the way they make use of dedicated IS perform better. The general lesson that can be derived from this evidence is that user characteristics should be compatible with the procedures that apply to them.

Proposition 2-5

Proposition 2-5: The better the fit between SeMa propensity and IS use, the higher the reliability.

We have seen that this proposition could not be validated in both our case studies. However, for the NPP Table 6.57 shows that a high spread in the SeMa propensity Scheme (DSScheme), i.e. a high homogeneity in combination with a high reliance on voice-based communication tools yields the lowest performance. This provides an indication that teams in the context of a NPP, that are homogeneously making sense out of a situation have no advantage in relying on rich media (voice-based). For them, a uniform dedicated system may be suitable since such systems allow for much less richness and diversity in communication channels. This does not come at a surprise in view of the highly standardized nature of the M&R work.

Proposition 2-6

Proposition 2-6: The more balanced the structural organization dimension, the higher the reliability.

H2-6a: Teams that work under close physical proximity perform better than teams that do not.

H2-6b: Larger teams are more reliable than smaller teams.

H2-6c: Teams with higher incident workload are more reliable than teams with a lower workload.

H2-6d: Teams with a greater deal of their time allocated to incident management are more reliable than teams with smaller time allocation.

H2-6a: Teams that work under close physical proximity perform better than teams that do not.

We have tested this variable by ranking the answer possibilities from little physical proximity to the IT headquarters, to high proximity. We have found evidence for the hypothesis on two levels: (1) proximity to the Bank's IT headquarters (DM4) and (2) team dispersion (DS4). Teams that (on average) are more based in the Bank's IT headquarters are performing better than teams that are not (DM4). In addition, a low spread in physical proximity is better for process reliability.

Also at the two-way ANOVA level, the results are interesting because of the general observation that low spread in physical location – i.e. low team dispersion – yields the highest reliability. This is particularly true for the non-urgent incidents. We also notice that reliability is the lowest when team dispersion is high. For the urgent incidents, this effect of team dispersion is countered by the impact of workload.

This finding indicates a strong influence of physical proximity on process reliability. Especially when seen in combination with the impact of Preoccupation with Failure the conclusions are important since dispersing a team from the headquarters can seriously negatively moderate the positive effect of HRO propensity. From the analysis of spread in physical location, we derive that team dispersion does not seem to be a good strategy either. In general, team dispersion results in low reliability. These conclusions can have important consequences for work organization and potentially constitute a modest addition to the large body of research on team effectiveness.

H2-6b: Larger teams are more reliable than smaller teams.

In the Bank Case, we have found no evidence for this hypothesis at the one-way ANOVA level. At the two-way level, there is an interaction with time allocated to incident handling work. Team size in itself does not seem to be a valuable explanation for the Bank's success. The other hypotheses under this proposition indicate that the measures that are derived from it do have a potential of explaining process reliability. In the NPP Case, we have found no proof for the validation of this hypothesis at the one-way ANOVA level. At the two-way ANOVA analysis level, it can be derived that in the majority of cases where team size moderates the effect of the independent variable on the dependent variable, large teams yield a lower reliability than small teams.

For urgent incidents, the highest reliability is obtained by small teams that perceive high pressure. On the other hand, small teams that perceive little pressure still yield a high reliability score. Large teams perceiving high pressure yield the lowest reliability and large teams perceiving low pressure manage are very reliable. Both Pressure and Team Size are strongly influencing a team's reliability, but their combined effect often is counterproductive. The highest reliability is obtained when their effect is mutually compensating. This can be explained through Loose Coupling Theory. Small team size (tight coupling) and low pressure (loose coupling), or vice versa are compensating each other. Judging from the data, when compensation should not be possible, a low value for both parameters is advisable. This cannot be explained by means of Loose Coupling Theory, but it could be assumed that the sole impact of operating as a small team is causing this relatively high reliability.

Small teams relying little on face-to-face communication are the most reliable, large teams the least in the handling of urgent incidents. Large teams, for that matter, can consistently increase their reliability when they (contrary to small teams), rely on face-to-face communication for the handling of urgent incidents. The first observation can be explained in the same way as above, namely that the impact of operating as a small team is causing this high reliability. The combination of large teams (loosely coupled) communicating face-to-face (tightly coupled) can be explained by Loose Coupling Theory.

Big teams communicating considerably through the dedicated system, yield the lowest reliability, whereas big teams that do not do so, see their reliability increase spectacularly. Small teams relying heavily on the dedicated system are the most reliable.

Again, it is shown that the influence of being a small team is important, but remarkable is the positive impact communication through a dedicated system can have, even with larger teams. The positive result of the combination of little use of dedicated systems for the communication (loose coupling) and bigger teams.

H2-6c: Teams with higher incident workload are more reliable than teams with a lower workload.

In the Bank Case, this hypothesis is validated, as well concerning the workload regarding the handling of urgent incidents as non-urgent incidents. Results from the two-way ANOVA support this finding with the exception of the combination with a high heterogeneity in the use of Peregrine for communication where a low workload shows the highest reliability.

In the NPP Case, we have been able to validate this hypothesis. Interestingly, the number of non-urgent notifications per employee is explaining the high reliability in the handling of urgent incidents.

This finding is remarkable at first sight, but can be explained quite easily. The fact that the incident pipeline is full causes a team to develop mindfulness in terms of attitude, procedures and mechanisms for dealing with non-urgent incidents. This mindfulness is bearing fruit for the handling of incidents. That data do not show an effect on the handling of non-urgent incidents as well does not necessarily mean there is no such effect. However, it just means that we have failed to reject the null hypothesis.

H2-6d: Teams with a greater deal of their time allocated to incident management are more reliable than teams with smaller time allocation.

We have found no evidence for this assertion at the one-way ANOVA level. At the two-way ANOVA level there is sufficient evidence that a low degree of time allocation leads to low reliability.

This is in line with our field observation and team reporting that the concentration on the incident handling is key in explaining a team's reliability. If a team is handling incidents as a sideline, with project work (e.g. software engineering) as primary activity, then the risk exist that a more sloppy incident handling job is done. We can think of three reasons for this. First, it can be considered normal since teams get no credit for handling the incidents correctly. Second, they are mentally much more preoccupied and interested by working on something new, than on fixing something old. Third, often the incident is a result from a bug or sloppy work done by a predecessor so team members feel little enthusiasm to clean-up somebody else's mess.

Proposition 2-7

Proposition 2-7: The better the fit between HRO propensity and the structural organization dimension use, the higher the reliability.

H2-7a: A high HRO propensity enhances the effect on reliability of teams working under close physical proximity.

H2-7b: A high HRO propensity enhances the effect on reliability of larger teams.

H2-7c: A high HRO propensity enhances the effect on reliability of teams with higher incident workload.

These hypothesis can be validated in the Bank Case (no data available for the NPP). This indicates the importance of the structural dimension for explaining high reliability. For instance, notice from **Table 6.38** that the more a team is based in the vicinity of IT headquarters, the more reliable it is. This can be explained by the fact that IM is at the heart of the activity over there, whereas this is less the case in other places of the organization.

Proposition 2-8

Proposition 2-8: The better the fit between SeMa propensity and the structural organization dimension use, the higher the reliability.

H2-8a: A high SeMa propensity enhances the effect on reliability of teams working under close physical proximity

H2-8b: A high SeMa propensity enhances the effect on reliability of larger teams

We have not been able to validate these hypotheses at an acceptable level of significance. Regarding the strong indication provided by the previous propostion regarding HRO propensity and structure, this may indicate that SeMa propensity is much less affected by the structural dimension. Future research should determine the validity of this statement.

Proposition 2-9

Proposition 2-9 *:* The more balanced the variety, the higher the reliability.

H2-9a: More experienced teams are more reliable.

H2-9b: The higher the variance in HRO propensity, the higher the reliability.

H2-9c: The higher the variance in Team Orientation, the higher the reliability.

H2-9d: The higher the variance in Threat Flexibility, the higher the reliability.

H2-9e: The higher the variance in Preoccupation with Failure, the higher the reliability.

H2-9f: The higher the variance in Sensitivity to Operations, the higher the reliability.

H2-9g: The higher the variance in Deference to Expertise, the higher the reliability.

H2-9b: The higher the variance in HRO propensity, the higher the reliability

At the Bank, we have found no support for this hypothesis at a sufficient level of significance on the one-way analysis level. On the two-way ANOVA level, we notice that the highest reliability is achieved for low spread in HRO propensity in combination with highly experienced teams, high use of e-mail. The lowest reliability is achieved for low spread in HRO propensity in combination with a less experienced teams and little use of e-mail.

At the NPP, there is no evidence at an acceptable level of significance for this assertion at the one-dimensional level. However, on the two-way ANOVA level, there is evidence for the hypothesis.

With respect to the handling of urgent incidents, the combination of a high variance in the spread of HRT propensity and a high spread in the degree to which team members adjust procedures leads to the lowest reliability. Other combinations are less pronounced since they range much less. Nevertheless, the lowest reliability can be observed for the combination of a low variance in the spread of HRT propensity and a low spread in the degree to which team members adjust procedures. A high spread in HRO propensity should be compensated by a low spread in the degree to which team members adjust procedures or vice versa (Orton & Weick, 1990).

Also at the NPP, regarding the handling of non-urgent incidents, the combination of a high spread in HRO propensity and a high spread in Threat Flexibility results in the lowest reliability. The highest reliability is obtained by teams with a low score on spread in Threat Flexibility and a high spread in HRO propensity. A high spread in HRO propensity should be compensated by a low spread in the degree of Threat Flexibility or vice versa (Orton & Weick, 1990).

As discussed in the Reconceptualization chapter (Chapter 4), this is in line with earlier findings by Waterman (1990) reporting on team composition. When membership is too homogeneous, reliability usually suffers. The reason is that such is goes at the expense of Team Orientation. The paradox however is, that too much Team Orientation in itself (as a result, a product) is bad for reliability. This conclusion is pushing the consequences of the need for requisite variety to the extreme: too much sugar wastes the taste. Therefore, once again, the dose makes the poison. Such leads to paradoxical situations, notably at the Bank, where this finding is reflected in double policy regarding team composition. On the one hand the Bank values heterogeneity among its staff and recruits people from a very diverse range of disciplines and backgrounds. It also deliberately breaks with too strong a team homogeneity by strongly stimulating – some would say, forcing – job rotation. On the other hand, it fosters homogeneity where it has been reported at several instances, that the Bank does not stimulate opposed views. This is mainly reflected in a deliberate recruiting policy of preferring school-leavers, bearing no marks of a past organizational culture or experiences. This duality cannot be observed in the NPP where homogeneity is the dominant leitmotiv and opposes the notion of requisite variety. This observation is in line with a general finding that high-risk industries, such as the nuclear industry, are characterized by homogeneity or low requisite variety (Aase & Nybø, 2002, p. 17). It is obvious that in systems that are as complex as our case organizations, a continuous balance needs to be strived for between team heterogeneity and homogeneity (Baker et al., 2006). On the one hand, team composition must be such that the compound effect of team members reaches a higher level of variance than is present in the system the team operates (Weick, 1987;Burke et al., 2005). On the other hand, effective interaction and communication still has to be feasible (Shea & Guzzo, 1987). In that respect, in HROs, a special role is reserved for the emergence of trust. A low degree of mutual trust between team members leads to a lack of cooperation and communication (Cox et al., 2006).

H2-9c: The higher the variance in Team Orientation, the higher the reliability

In the Bank Case, this hypothesis cannot be validated. The highest reliability can be found for urgent incidents for low spread in Team Orientation in combination with low score on Enactment, on registration in the dedicated IS and for non-urgent incidents for low spread in enactment as well. In the NPP Case, the hypothesis cannot be validated significantly at the one-way ANOVA level. On the level of two-way ANOVA however, some conclusions can be drawn. For instance, the combination of a high variance in Team Orientation and a high degree of Sensitivity to Operations yields the worst reliability. A low spread in Team Orientation combined with a high degree of Sensitivity to Operations yields the best reliability. A high degree of one property should be altered by a low degree of the other property (Orton & Weick, 1990). Also in the NPP Case, a high variance in Team Orientation and a high degree of Team Orientation yields the lowest reliability and a high degree of Team Orientation and a low spread in Team Orientation. This is a strong indication for the relevance of Team Orientation as a construct.

H2-9d: The higher the variance in Threat Flexibility, the higher the reliability.

At the Bank, this hypothesis is falsified. As well for urgent as for non-urgent incidents, the lowest variance yields the highest reliability. At the NPP, on the one-way ANOVA level, we have found no evidence for this hypothesis at an acceptable significance. At the two-way ANOVA level we have found support for this hypothesis in combination with a high degree for the number of urgent incidents per employee. A low spread in Threat Flexibility in combination with a low average number of urgent incidents per employee yields a high reliability as well. It is obvious however, that the number of urgent incidents per employee on itself is a strong explanation for organizational reliability. Remarkable however is the compensating influence of a high spread in Threat Flexibility on reliability when combined with a low average number of urgent incidents per employee. Reliability drops considerably. However, when this low number of urgent incidents per employee is studied in combination with a low spread of Threat Flexibility reliability increases. In terms of coupling this is an example of loose – tight, thus explaining high reliability (Orton & Weick, 1990).

Also at the NPP, for the handling of urgent incidents a low spread in Threat Flexibility yields the highest results when seen in combination with a low degree of several constructs. Based on these findings, for face-to-face communication it becomes obvious that a desirable combination would be a low degree of face-to-face communication and a low spread in Threat Flexibility.

H2-9e: The higher the variance in Preoccupation with Failure, the higher the reliability

In the Bank Case, this hypothesis could not be validated at the one-way ANOVA level. At the two-dimensional level, a low spread in Preoccupation with Failure generally yields the lowest reliability. In the NPP Case, this hypothesis could not be validated at an acceptable level of significance at the one-way ANOVA level. For urgent incidents, a high variance in Preoccupation with Failure only yields a high reliability when combined with a high variance in the way teams deviate from procedure. Where teams deviate from procedure is more homogeneous, reliability is the lowest. The highest reliability is obtained with a combination of a low variance in Preoccupation with Failure and a low variance in the way teams deviate from procedure. This is in line with what is suggested by HRT literature. A high homogeneity of Preoccupation with Failure is good, independent whether this score should be high or level in order to obtain high reliability. In combination with Team Orientation, the highest reliability is obtained with low Team Orientation and a high variance in Preoccupation with Failure; the lowest reliability is obtained with a high degree of Team Orientation and a high variance in Preoccupation with Failure.

H2-9f: The higher the variance in Sensitivity to Operations, the higher the reliability

At the Bank, this hypothesis cannot be validated at the one-way ANOVA level. For urgent incidents, a combination of low spread in Sensitivity to Operations and a low spread in Preoccupation with Failure yields the highest reliability. The lowest reliability is obtained with a combination of high variance in the degree of Sensitivity to Operations and a high variance in Threat Flexibility. This might indicate that the homogeneity of a team at this point is essential for its reliability. On the other hand, the highest reliability is obtained for a high variation in the Sensitivity to Operations construct if combined with a low degree of variance in the Threat Flexibility construct or for the inverse, i.e. for a low variation in the Sensitivity to Operations construct if combined with a high degree of variance in the Threat Flexibility construct. This observation could be explained through the Loose Coupling paradigm.

H2-9g: The higher the variance in Deference to Expertise, the higher the reliability

In the Bank Case, this hypothesis could not be validated at the one-way ANOVA level. On the two-dimensional interpretation, we notice that the highest reliability is achieved for the combinations of low spread in Deference to Expertise and other factors, especially for urgent incidents. In the NPP Case, this hypothesis cannot be validated at the one-way ANOVA level at an acceptable level of significance. This stresses the complexity of the phenomenon since it cannot be explained unidimensionally. For the handling of urgent incidents, the average number of urgent incidents per employee strongly affects the process reliability. The highest reliability is achieved for a high spread in Deference to Expertise, when employees have an on average high number of incidents to handle. However, the combination of a low average number of urgent incidents per employee and a low spread in Deference to Expertise yields a high reliability as well. Such is a remarkable conclusion, because we have seen at the one-way ANOVA level that the Deference to Expertise construct has a convincing influence on organizational reliability. Our reading of these data is that low pressure/efficiency drivenness is an expression of loose coupling, which is compensated by a low spread in the degree of Deference to Expertise, which is an expression of tight coupling.

A combination of a low score on SenseMaking properties and a low score on variance in Deference to Expertise yields the lowest reliability. The highest reliability is obtained for a low score on these constructs in combination with a high spread in Deference to Expertise. The high scores can be explained through Loose Coupling Theory. Despite a high score on SenseMaking propensity (loose coupling), the overall reliability is low, because of reinforcement by a high spread in Deference to Expertise (i.e. loose coupling).

Proposition 2-10

Proposition 2-10: The better the fit between HRO propensity and variety, the higher the reliability.

H2-10a: Teams that perceive Threat Flexibility more homogenously perform better than teams that do not.

H2-10b: Teams that perceive efficiency drivenness more homogenously perform better than teams that do not.

H2-10a: Teams that perceive Threat Flexibility more homogenously perform better than teams that do not.

A high homogeneity (i.e. low spread/variance) in the perception of the Threat Flexibility construct yields the highest reliability, as well for the handling of urgent as of the non-urgent incidents. When a team has about the same perception of Threat Flexibility it means that there is little ambiguity in the direction pointed out by management. This straightforwardness and univocality might very well be contributing to the team's reliability because it simultaneously reduces complexity and allows for the necessary degrees of freedom to cope with the unexpected. We argue that Threat Flexibility, as a newly distinguished HRO construct, is univocally positive: it has no side effects, there are no caveats, and there is no catch. This has considerable consequences for management and the practice of organization design. Because of the observed straightforwardness of the construct, it can be administered quite easily in settings that are comparable to the organizations and processes we have studied.

H2-10b: Teams that perceive efficiency drivenness more homogenously perform better than teams that do not.

Both for the Bank and the NPP, we remark that the higher the homogeneity in the perception of efficiency drivenness, the higher the reliability. This demonstrates the importance of a low degree of variance in the perception of efficiency orientation to achieve high reliability. At this level, a team's shared interpretation of the orientation towards efficiency is determining for a team's reliability. Despite what we have argued regarding the necessity of requisite variety, this determinant clearly indicates the necessity of a policy that aims at a clear communication and consequent management.

Proposition 2-11

Proposition 2-11: The better the fit between SeMa propensity and variety, the higher the reliability.

H2-11: More experienced teams, relying more on SeMa propensity, are more reliable.

We have not been able to validate this hypothesis at an acceptable level of significance. Since experience did not seem to matter in general throughout our data analysis. We are inclined to conclude that experience is not relevant for explaing high reliability, nor is it providing any information on the HRO or SeMa propensity a team has.

Chapter 8 Conclusions

Science becomes dangerous
only when it imagines
that it has reached its goal
George Bernard Shaw

This chapter draws conclusions from the research presented in the previous chapters. First, the answers to the research questions raised at the beginning of this dissertation are summarized (Section 1). Subsequently, this thesis' main contributions are presented (Section 1.3) and its limitations acknowledged (Section 3). The chapter concludes with an identification of directions for future research (Section 4).

1 Answering the Research Questions and Main Findings

1.1 RQ1 – Are the organizations HROs?

Both our case studies can be called HROs since HRO characteristics, as the ones described in HRO literature are observable in both organizations [RQ1-1]. In addition, our data have shown that it are the same constructs that are observable [RQ1-2]. In general, the NPP (as an archetypical HRO) has the highest values on HRO properties [RQ1-3]. The first research question therefore can be answered affirmatively. However, our research has also pointed out that a NPP, although theoretically an archetypical HRO, in fact is not really a HRO, but an Ultra Reliable Organization (URO). The Bank on the other hand, is much more a HRO than originally hypothesized because of the day-to-day exercise of seeking equilibrium between effectiveness and efficiency.

1.2 RQ2 – What constitutes high reliability?

The answer to this research question is much less univocal than the answer to the first research question. In general, we can conclude that HRO and SeMa constructs do not necessarily positively influence process reliability [RQ2-1], but that the dose makes the poison. Starting from a reconceptualized theoretical framework, we have observed that newly introduced factors such as Team Orientation, Threat Flexibility and Efficiency, univocally contribute to reliability. Despite the fact that there is not something like an ideal '*reliability cocktail*' fully explaining reliability [RQ2-2], there are strong indications that a reconceptualized HRT offers valuable advice for the design of processes that are needed to be highly reliable. The same conclusion can be reached when comparing the composition of the reliability cocktail from one team to another [RQ2-3]. Indeed, we have found that contextual and structural dimensions (e.g. team size, workload and time allocation) have an important moderating impact on high reliability parameters influencing a team's reliability.

1.3 Main Findings: HRO paradoxes

Bourrier (1996), in her study of French and US Nuclear Power Plants, found out that two NPPs that were organized in a totally different way, yet both demonstrated impressive records of safety and productivity. "*One French NPP showed little common socialization among workers. Worker skills were only tacitly acknowledged by management, for example by implicit gaps in procedures. For workers on the other hand, filling in these procedural gaps as they performed their task was the only acceptable/reasonable strategy if they wanted to be seen as competent, and, therefore worthy of retaining some measure of autonomy and power*" (Bourrier, 1996, p. 105). Bourrier's observation goes to the heart of what we label the 'HRO paradox': an ardent acknowledgement of the blessings of mechanistic organizing, without losing sight of common sense. Essential in this respect is not to exaggerate so that core competencies never turn into incompetencies. Rochlin captures this innate HRO paradox as follows: "*In short, these organizations seek an ideal of perfection but never expect to achieve it. They demand complete safety but never expect it. They dread surprise but always anticipate it. They deliver reliability but never take it for granted. They live by the book but are unwilling to die by it. If these beliefs seem wonderfully contradictory, those who express them are under no particular pressure to rationalize their paradoxes; indeed, they seem actively to resist such rationalization. We often hear the whole spectrum expressed by a single individual over the course of an interview or series of discussions*" (Rochlin, 1993, p. 24).

The remainder of this section deals with the background of this paradox: What is the relevance (advantages and disadvantage)? How can it be explained? How does it show itself in everyday organizing?

1.3.1 The dose makes the poison

Roberts and Bea (2001b, p. 181) warn that organizations can develop core competencies that later turn into incompetencies. Core competencies are sets of skills, complementary assets and routines that provide the basis for an organization's survival and prosperity. In this section, we emphasize that what can be considered as core competences of HROs can become incompetencies. This is a paradox in the sense that 'much can be *too* much and little too little'. HROs capable of finding the balance between both extremes can truly call themselves High Reliability Organizations. The others can do so maybe just in name. In our view, this balancing is most characteristic for HROs. To make our point, we first dwell on the paradoxical nature of HROs. We subsequently deal with the duality between procedure and improvisation (Subsection 2), standardization and requisite variety (Subsection 3), hubris and confidence of self and the other (i.e. trust) (Subsection 4).

1.3.2 Working smarter

A first argument can be found in the complexity of reality. Today's organizational setting has nothing to do with the linear environment of a few decades ago (e.g., what you produce will be sold). In business and academic journals, in the rhetoric of consultants, in public relations talk, on websites, etcetera, lip service is paid to the dynamics of the environment and the strategies that emerge from it. In practice however, organizations do not tend to do what they preach: instead of embracing complexity, they reduce (i.e. try to destroy) it by means of key reliability indicators (KPIs), balanced scorecards, and the like. If what we state is true, we should see organizations fail in large numbers, but remarkably, they do not. What happens is that organizations cope with this reality in their own way, a way that is familiar to them and where they are good at: by working hard. Reorganizing, rescheduling, re-engineering, hiring more staff, new projects, new technologies, implementing new strategies … are part of this 'working hard' approach. Therefore, stress levels are high, communication becomes difficult or equivocal and budgets are used at the speed of light. HROs though are organizations that have found a way around this working harder strategy; instead of working harder, they work smarter. By this is meant that instead of putting more effort in operations, they invest this energy in the build-up of organizational capability: by training, by smart design, by working on a culture of flexibility and reliability. Organizations that invest in improvement will experience increasing capability and find that they have more time to allocate to working smarter and less need for heroic efforts to solve problems by working harder (Repenning & Sterman, 2001). No matter how appealingly straightforward this idea might be, non-HRO managers do not apply it in their everyday practice. This is not only because they might not be aware of this inherent dynamics, but also because it is simply not rewarding to invest in capability:

(1) The effect is not noticeable until after a long time whereas the effect of working harder is quasi immediate.
(2) The means that are needed for a working smarter approach are esteemed to be more needed elsewhere in the organization (working harder).

This idea has been developed by Repenning and Sterman (2001) when coining the term *Capability Trap*. In the short run, there is nothing that urges the organization to do things differently and on the condition that enough resources become available to continue to put the necessary effort in the working harder approach, even in the longer run the failure will not materialize. The opportunity cost however is high.

1.3.3 Stability in cognition, variance in design

Early work on HROs characterized high reliability in terms of the role of repeatability and routines in avoiding adverse consequences (Roberts, 1990b). However, more recent work portrays reliable outcomes as the result of stable processes of cognition, such as vigilance or monitoring, directed at variations in work activities (Weick et al., 1999). HROs show variation in activity, but that what makes a HRO typical is stability in the cognitive processes that make sense of this activity. HROs seem to have stopped treating stable patterns of activity as the source of reliable outcomes. Ramanujam and Goodman (2003, p. 816) point out that this represents a shift in focus from processes that aid repeatability of operations to the role of stable cognitive processes in managing the variability inherent in HRO work activities, but that the focus remains reliable outcomes (i.e., avoidance of adverse consequences). Of all HRO scholars, Schulman probably has phrased this best (Schulman, 1993b, p. 369) in his analysis of Diabolo Canyon: "*The proposition that emerges from analyzing Diabolo Canyon is that reliability is not the outcome of organizational invariance, but, quite the contrary, results from a continuous management of fluctuation both in job reliability and in overall department interaction*". Put differently: it is not that HROs do not experience failures or deviations from the expected, but these events do not disable them. They deal with them.

For a comprehension of the cognitive mechanism behind this characteristic behavior we refer to Weick et al (1999, p. 87): "*[To be] opportunistic and flexible in order to detect and to adapt to events which require revision of situation assessment and plans … problem solvers need to revise* *their understanding of the situation, the evidence collection and evaluation tactics, or their response strategy when new events are detected and evaluated. Failures to revise in any of these ways produce what are seen as fixation failures*". By separating the variation and stability folded into design and routines, and assigning the variation to routines and the stability to processes of cognition, stable patterns of activity are no longer treated as the source of reliable outcomes (Weick et al., 1999, p. 87).

1.3.4 Dynamic adaptation

Therefore, good design in essence is *not* about rigidly preventing incidents, accidents and crises, but about a design for a reliable management of them. This is confirmed by Lin & Carley (Lin & Carley, 2001) when they write: "*If crises are indeed inevitable, then the more important question is not about how to design the organization to avoid crisis, but how to design the organization for high reliability during a crisis. Re-framing the question in this way gives rise to an entire new set of concerns. Is the organizational design that exhibits high reliability during a crisis also optimal under non-crisis conditions? Is it reasonable for organizations to design for crisis, or should organizations alter their designs when faced with a crisis? In other words, is dynamic adaptation called for? Further, if organizations do restructure, what will be the most effective new structure?*" An onset to the answer to this pertinent design question is provided by Weick et al. (2005): "*If one looks to see what constitutes this reliability, it cannot be found in any single element of the system. It is certainly not to be found in the equipment….for a period of several months during our field work it was failing regularly….Nor is it to be found in the rules and procedures, which are a resource for safe operation but which can never cover every circumstance and condition. Nor is it to be found in the personnel who, though very highly skilled, motivated and dedicated, are as prone as people are everywhere to human error. Rather we believe it is to be found in the cooperative activities of controllers across the 'totality' of the system, and in particular in the way that it enforces the active engagement of controllers, chiefs, and assistants with the material they are using and with each other*" (Weick et al., 2005, p. 418).

2 Main Contributions

However modest in the light of an eminent research track as HRT, this study claims to have made some relevant contributions. Despite its high relevance for society, 'Reliability' has not always been given appropriate research consideration, resulting in some notable shortcomings. Our research has attempted to remedy these shortcomings. To clarify this, we decompose this dissertation's title – <u>Two cases</u> in <u>High Reliability</u> <u>Organizing</u>: a <u>Hermeneutic</u> <u>Reconceptualization</u> – since every word has its meaning. In that respect we first explain the relevance of the double case study approach (2.1). Subsequently we summarize the relevance of our findings for the field of HRT (2.2), paying special attention to the distinction between *organization* and *organizing* (2.3). Next, the hermeneutic research methodology is dealt with (2.4) and the major conclusions concerning the Reconceptualization are presented (2.5). Finally, as a form of synthesis of the above, the question is addressed whether the theorizing on HROs can be labeled a theory (2.6). It should be noted that categorizing this research's contributions under these labels should not be seen as completely exclusive, or as limitative. Many of the contributions are the result of a combination of theory, method and data, fully in line with our hermeneutic approach. When they are discussed as presented below, it is for analytical reasons.

2.1 Two cases

'A Bank can learn from a Nuclear Power Plant and vice versa'. That statement has been the starting point of our research, now five years ago, and as is shown in the previous section, it more or less has remained intact. We are convinced that we thank this to the research design and research ambition. More particularly, we feel we have empirically broadened the HRT field in three ways that are novel in HRO research and find their origin in the double case study approach underlying our study:

- The application of HRT to the Incident Management Process;
- By applying HRT in the context of a mainstream highly reliable (garden variety) organization;
- The comparison of a mainstream highly reliable organization to an archetypical HRO;

Many aspects of these contributions have been presented in detail in this dissertation and need no further elaboration, so that in the remainder of this subsection, we can suffice with a discussion of those contributions that might need further elaboration. We subsequently deal with the extension of HRO research to the context of Incident Management (2.1.1), the question whether garden variety organizations can learn from archetypical HROs (2.1.2) and vice versa (2.1.3).

2.1.1 Incident management process

As we have shown in our review of literature, the field of application of HRT, although substantial, still is focused on a limited number of processes and contexts. By expanding this scope with a case study on the high reliability of the (IT) incident management process, we are convinced that we have made a double contribution: First, we have brought within reach the HRO community's ambition to expand its natural habitat. Second, we have accepted the invitation to study the usefulness of HRO concepts in the IS domain (Butler & Gray, 2006). We therefore hope that our study has created an opening towards more HRO case studies in the field of IS.

*2.1.2 Can '*garden variety*' organizations learn from archetypical HROs?*

Can mainstream organizations – or '*garden variety*' organizations (Roberts, 1993, p. 2) – learn from archetypical HROs? We believe the *a posteriori* answer is double: yes and no. The answer is *no*, because archetypical HROs in fact are not HROs but UROs, so that a comparison without nuance is not relevant. The answer is also *yes*, because there are hallmarks from NPPs that can be applied to other contexts (e.g. introducing time-outs, non-punishability, decoupling process design, etc.), as discussed in the body of this dissertation.

2.1.3 Can archetypical HROs learn from garden variety organizations?

Furthermore, we have learned that an archetypical HRO can learn from a non-archetypical as well. We take the advice of Creed et al. seriously when they posit that: "*Only by finding variance in what is claimed to be the outstanding feature of these organizations – their overreaching concern for reliability – can we begin to examine just how the politics of technology and the culture of reliability develop differently over time. By searching for neighbors, we may find that HROs are oriented toward avoiding ineffectiveness to the near conclusion of trying to reach effectiveness. As we move down to the reliability continuum, we may find a more balanced* *addressing of both effectiveness and ineffectiveness criteria. By studying these phenomena we can begin to untangle criteria for both*" (Creed et al., 1993, p. 71-72). HROs as described in literature are of limited relevance for mainstream context because of their exclusive focus on effectiveness. In reality, organizations do not have this luxury and must constantly balance between a striving for effectiveness and the economic imperative to use resources efficiently.

2.2 High Reliability

This study has contributed to the fine-tuning of what constitutes high reliability. More particularly, we feel we have empirically broadened the HRT field in four ways that are novel in HRO research and that find their origin in the explication of the high reliability concept:

- By applying HRT to the study of organizational reliability, instead of the more common issue of safety;
- By explicitly and empirically testing the impact of HRO properties (independent variable) on reliability (dependent variable);
- By incorporating in this conceptual model structural and contextual dimensions that are potentially moderating the impact of HRO properties on reliability;
- By measuring HRO properties not solely in terms of averages, but also as spread.

First, we explain in what way this study has accomplished reaching an encompassing definition of reliability (2.2.1). Next, we explicate the relevance for HRO research of taking reliability as a dependent variable (2.2.2). Then we point out the relevance of incorporating moderator variables in the research design (2.3.3). We conclude with pointing out the relevance of working with spread in HRO properties, next to working with mean observations.

2.2.1 A definition of reliability

A shortcoming in research on reliability is that, at least from an academic point of view, the concept of reliability itself has not been defined univocally and holistically. Even though many scholars have given an accurate description of this concept, most of their research takes a particular viewpoint. As such reliability studies deal with manufacturing reliability, organizational reliability or safety, but not with an all-compassing reliability that takes a systems perspective and acknowledges social, human, economic or technological aspects. Besides, few studies exist on the interrelation between task environment and organization design on how this influences organizational reliability (Lin & Carley, 2001;Pearson & Mitroff, 1993). We have addressed this shortcoming by taking a systems perspective to reliability.

2.2.2 Reliability as dependent variable

Another contribution of our work is that it does not take a dependent variable as a starting point for the selection of our cases, an approach typical of NAT and HRT research (Rosa, 2005, p. 232). We have taken the systems interactive complexity and tight coupling as a start, not their assumed well-oiled functioning or their past of dramatic incidents or accidents. The starting point are two organizations/processes that can be characterized as interactively complex and tightly coupled without categorizing the organization of the case as a whole as highly reliable. Since we are not working back from empirical evidence, we believe in the generalizability (or transferability) of our findings even though we have merely studied two cases in depth. Noteworthy in this respect is also that our study of process reliability through the technique of

Repeated Measures Analysis of Variance since it has permitted us to have a more nuanced view on reliability by taking into account the spread in the data. We argue that this is a far more realistic picture of reliability than taking a snapshot or than taking a mean observation as dependent variable.

2.2.3 HRO properties as mean and as variance

To the best of our knowledge, literature up to now has not operationalized the nuanced character of High Reliability thinking. Our research claims it has done so by incorporating in its design the spread in observations between team members. In line with the Requisite Variety idea (*Various Variances*), we have shown that examining a team's standard deviation on particular variable can be revealing for explaining reliability.

2.3 Organizing

We are convinced that 'HRO' is the right acronym for the type of organization studied by HRT. However, based on our findings, we argue that it should not be used for 'High Reliability Organization' but rather for 'High Reliability Organizing' (Berniker & Wolf, 2001, p. 26). There is a double rationale for this: being highly reliable is dynamic (2.3.1) and it makes the joining in with mainstream organization science more feasible (2.3.2).

2.3.1 Reliability is dynamic

We believe that the HRO concept has value as a verb, not as a noun. By this we imply that the nature of HROs is dynamic, not static. Indeed, reliability is a dynamic non-event (Weick, 1987), and a continuous effort is necessary for finding an equilibrium that is perishable and will be replaced by a new equilibrium. We have investigated the mechanisms and interferences that play a role in achieving high reliability and demonstrated the impact of contextual and structural dimensions other than those proposed by HRT literature on organizational reliability.

2.3.2 HRT as guide for organization science

We are convinced of the potential of HRT as a guide for organization science. The problem with past and contemporary HRO research is that its practical application still is very much underdeveloped or unrevealed. For this reason, HRT seems incapable of joining in with mainstream organization theory. In a recent contribution to *The Blackwell Encyclopedia of Management*, Karlene Roberts puts it like this: "*Today, the research [on reliability] flourishes, although it has not been well tied to mainstream organizational theory*" (Roberts, 2005, p. 157). This is the fundamental objective we had with our work: tying insights from high reliability thinking into mainstream organization theory and mainstream organizational learning (Van Den Eede et al., 2004). Our research has addressed this by investigating whether and how HROs can learn from garden-variety organizations. We posit that the study of HROs, using similar approaches as described in this dissertation, can offer additional guidance in the study of organizations of all types.

We believe this dissertation has made a modest contribution to the study of organizations in closing what could be called the *Weick Circle*. By this we mean the process of reading Weick's oeuvre backwards by studying Loose Coupling (Weick, 1976; later reconceptualized in Orton & Weick, 1990), The Social Psychology of Organizing (Weick, 1979), SenseMaking (Weick, 1995); High Reliability Organizations (Weick et al., 1999), back to organizing, coupling and SenseMaking.

2.3.3 Moderator variables

In line with Drazin and van de Ven (1985), our research has examined the effects of multiple contextual or structural factors on reliability. Multiple factors like team size, experience, physical location etc., have shown to be important in explaining reliability. We have found adopting a systems approach is uniquely valuable in addressing research questions as the ones we have raised in this study.

2.4 Hermeneutic

We have taken Drazin and van de Ven's (1985) advice at heart and have combined research approaches for the study of contingency. Following a Systems Approach to organizational reliability, we have not sufficed with a mere focus on how single contextual factors and single structural characteristics affect each other and how these pairs of context and structure factors interact to explain reliability. Nevertheless, this kind of reductionism is important in our research. The reason is that it "*treats the anatomy of an organization as being decomposable into elements that can be examined independently. The knowledge gained from each element can then be aggregated to understand the whole organizational system*" (Drazin & van de Ven, 1985, p. 529). However, the systems perspective added to the holism that resulted from the combination of an intra- and inter-case analysis, from a triangulation of theory and method. The combination of reductionism and holism offers potential for general contingency-theory research. With Drazin and van de Ven (1985), we posit "*that contingency studies should be designed to permit comparative evaluation of several forms of fit. The resulting complementary information can lead to more comprehensive descriptions of context structure- reliability relationships than a single approach to fit alone. By examining multiple approaches to fit in contingency studies and relating these findings to unique sample characteristics, one can develop mid-range theories of fit*".

HRT seems to favor the empirical or case approach. Management is studied by analyzing experience, usually through cases. "*It is based on the premise that students and practitioners will understand the field of management and somehow come to know how to manage effectively by studying managerial successes and failures in various individual cases*"(Koontz, 1980, p. 177). HRT acknowledges the contingency or situational approach to management theory. NAT obviously makes the distinction between situations depending on the degree of coupling and complexity. HRT scholars place themselves in the same framework by adopting this same terminology. On the other hand, they are not contingency-driven where they leave their descriptive role and take a normative tone when proposing treatments. In this sense they seem to ignore that there is no "*one best way*" and are *"often overlooking the fact that intelligent practicing managers have always tailored their practice to the actual situation*" (Koontz, 1980, p. 177).

The cornerstone of the hermeneutic approach underpinning our research is its multiple-case character. Because of the identical research build-up in both our cases, we were capable not only of data-theory triangulating within-cases, but also in between them. This '*twin*' approach is quite exceptional in HRO research, where theory development is based on individual case studies, leading to a "*danger of falling victim to a kind of evolutionary optimism that infers that because features have evolved in an organization that is surviving in a high-reliability niche, these features must all contribute to its overall reliability. In research on high reliability in* *organizations, we are beset by the problem of many variables and few cases. How, without more failures, can we really be sure which of the many organizational features we see are in fact adding to reliability?*" (Schulman, 2001, p. 347).

Another contribution this research makes is in the way it combines scientific and practical relevance. Scientific research and consulting, especially in environments like the ones we have studied, are separated most of the time. It is rare that scientists are involved in decision-making and that they are in a position to share their expertise with the highest level of the organization (Bourrier, 2005, p. 99). In this, our research differentiates itself, because it has been commissioned by the organization's senior management. Our research findings, for this reason, have the potential of being translated and implemented into organizational practices and design.

Another significant contribution of this research is that it adds to the body of quantitative research in this field. As for HRT, prior empirical data was gathered only in the following cases, to the best of our knowledge:

- Vogus and Welbourne (2003b) provided an indirect, partial test of the connection between collective mindfulness and innovation activity in new (IPO) software firms, suggesting that human resources practices are the mechanisms by which three of these processes develop and lead to mindfulness (Knight, 2004, p. 13);
- Schulman (1993a;1993b) examined the Diabolo Canyon NPP on its high reliability;
- Rochlin, La Porte & Roberts (1987) and Roberts, Rousseau & La Porte (1994) on Nuclear Power Aircraft Carriers ;
- Knight (2004) provided a test for the relationship between collective mindfulness and safety in public swimming pools.

As for as NAT, even fewer empirical studies are available:

- Berniker and Wolf (1999;2001;2007) provided evidence for NAT in the oil refinery sector.
- Sagan (1993) did the same in the field of nuclear warfare technology.

All in all, this constitutes a limited body of empirical research. Our research as such is one of the few studies that systematically examines the direct effect of both high reliability and Sensemaking properties on organizational reliability.

2.5 Reconceptualization

2.5.1 Towards a balanced theory on High Reliability by including Efficiency

If mindfulness is defined only in terms of favorable outcomes, then it is always a positive thing (Rerup, 2005). "*Because theory needs to specify circumstances under which the positive consequences outweigh the negative, and vice versa, it follows that a 'balanced' theory of mindfulness will have to specify both the costs and benefits incurred by being mindful. As theorizing about mindfulness continues, I expect the literature to develop an appreciation for both the costs and the benefits of mindfulness*" (Rerup, 2005, p. 467-468).

The factor analysis we conducted was relevant in this regard, as it (re-)produced a majority of the major themes in the conceptual framework. This occurred despite the fact that the items were not strictly grouped by theme in the questionnaire. This provides empirical support for the clustering of characteristics into a set of themes that is a combination of the two schools of thought in the HRO discipline.

The purpose of our research was to propose a process 'theory' of the relationship between constructs and insights stemming from different theoretical perspectives on organizational reliability. Therefore, the elements of our work by themselves are not novel; throughout the dissertation, we have indeed extensively acknowledged our debt to the groundbreaking theoretical work of the authors we build upon. What we do claim as novel, however, is our selection, reinterpretation and rearrangement of these elements. This combination of analysis and synthesis bears the promise of shedding a broader and more precise light on what constitutes organizational reliability. The systemic blend of analysis and synthesis we have developed here has the potential of explaining conflicting empirical results and of suggesting guidelines for future research (Soh & Markus, 1995, p. 30).

The concepts, used in this reconceptualization process, are not things we *see* in reality, but constructs that emerge from our insight in order to help us understand reality (Singer, 1983, p. 85). Understanding how reliability, flexibility, coupling and other organizational constructs relate to each other is a necessary step in building construct validity (Hinkin, 1998;Knight, 2004, p. 16). Furthermore, understanding how they interrelate is vital when the purpose is to link our findings to the broader organizational theory domain (Weick et al., 1999;Knight, 2004, p. 16-17).

2.5.2 Bridging the dichotomy between the Berkeley and the Michigan School

As we have argued in Chapter 2, the Michigan school of thought pays more attention to the notion of culture (as contextual dimension) whereas the Berkeley group favors the structural dimensions (e.g. the notion of bureaucracy) (Eisenhardt, 1993, p. 133). In this sense, the Michigan school takes independent dimensions (causes)[73], the Berkeley school dependent dimensions (effects from the independent dimensions) as starting point for understanding the concept of high reliability. Our reconceptualization has tried to strike a balance between both views as it combines constructs originating from both schools, by adding the causality that is missing in the Berkeley school. For instance, we added the constructs of Team Orientation and Threat Flexibility as the cause of the cultural dimension.

2.5.3 Bridging the dichotomy between HRT and NAT

Another limitation addressed by our research regards the two dominant bodies of literature: High Reliability Theory (HRT) and Normal Accidents Theory (NAT). "*While the notion of high(er) reliability is theoretically justifiable, to the best of our knowledge, HRT and NAT have undergone only limited empirical testing. This might be due to the acute problem in reliability research that mainly consists of case studies examining the background of effective action or catastrophic failure (e.g., Perrow, 1984; Shrivastava, 1987; Vaughan, 1996; Weick, 1990, 1993) in reliability seeking organizations*" (Ericksen & Dyer, 2005, p. 8). Our research takes the advice of Erickson and Dyer (2005, p. 10) at heart, and has aimed at a merging in thinking across the case studies and empirical testing, hence making a contribution to Reliability literature. We believe we have succeeded in doing so by developing a nuanced view on the notions both theories have in common – those of complexity and coupling. Snook (2002, p. 204) gives three reasons for the origin of conflicting insights between HRT and NAT with regard to how reliability should be guaranteed: "*Part of the answer lies in our inherent limitations as information processors. Part of the answer lies in our linear deterministic approach to causality. And, part of the answer lies in the inherent unpredictability of events in complex organizations*". The nuance we brought into the debate relates to the (re-)introduction of paradigms regarding efficiency vs. effectiveness; reliability vs. flexibility; sense making vs. decision making; tight vs. loose coupling; improvisation vs. procedure; stability vs. instability, etc. One of the objectives of our study was to make these approaches less conflicting. We did so by taking the discussion a bit further than the traditional conclusions from contingency theory. We address the question whether there are design and behavioral characteristics that are robust – in the sense of reliable and flexible enough – to allow for an '*all-seasons*' approach to organizational reliability.[74] This kind of studies seems to be rare. Lin & Carley (2001) report that there are few studies that compare organizational designs with an eye to reliability and that there is no research that compares actual behavior with a formal model. In more dynamic environments – such as in our case studies – flexibility is a stronger predictor for reliability than stability (Anand & Ward, 2004).

2.6 Theory

Kurt Lewin said: "*Nothing is as practical as a good theory*"(Lewin, 1945, p. 129). Popper asked: '*What is a theory*?' and Weick showed us that even a bad 'theory' can be practical.[75] Therefore, theories provide a lever to see more than there is to see without the application of a theoretical framework. However, theory must be explaining reality and not just be 'theoretically' correct. Science outside of societal problems is at best nothing more than intellectual '*Spielerei*' (Behnke & Behnke, 2006). Hence, the question arises whether HRT genuinely is a theory. We could suffice here to prove the importance of High Reliability Theorizing, for the study of reliability – which is after all what the HRO discipline has proved over the years to be capable of – but we dig a little deeper into its essence as a theory, in the hope of finding clues that could better specify its value. We clarify how our research has answered the question whether HRT genuinely is a *theory*. To this end, we ask the question whether HRT is a *theory* in the scientific sense (2.6.1) and what type of theory HRT is (2.6.2).

2.6.1 Is HRT a theory?

The question what theory is and is not has practical implications for the quality of organization science. This is discussed in an issue of the Academy of Management Review (1989, Vol. 14, Issue 4, e.g. Eisenhardt, 1989;Weick, 1989), which focused specifically on theory and theory development. Similarly an issue of Administrative Science Quarterly (1995, Vol. 40, Issue. 3, e.g. Sutton & Staw) contained articles about what theory is, what theory is not and how theorizing occurs. However, multiple views of theory exist. Differences in these views depend to some degree on philosophical and disciplinary orientations, yet there are also commonalities (Gregor, 2006), centered around abstraction and generalization about phenomenon, interactions and causation.

Table 8.1 shows the components of theories (Gregor, 2006), allowing us to identify what components HRT is composed of.

Theory component	*Definition*	*HRT (in this dissertation)*
Means of representation	The theory must be represented physically in some way: in words, mathematical terms, symbolic logic, diagrams, tables or graphically.	Chapter 5
Constructs	These refer to the phenomena of interest in the theory. All the primary constructs in the theory should be well defined.	Chapter 4
Statements of relationship	These show relationships among the constructs. Again, these may be of many types: associative, compositional, unidirectional, bi-directional, conditional, or causal.	Chapter 5
Scope	The scope is specified by the degree of generality of the statements of relationships	Chapter 5
Causal explanations	The theory gives statements of relationships among phenomena that show causal reasoning	Chapter 5
Testable propositions (hypotheses)	Statements of relationships between constructs are stated in such a form that they can be tested empirically.	Chapter 6
Prescriptive statements	Statements in the theory specify how people can accomplish something in practice, e.g., construct an artifact or develop a strategy.	Chapter 7

Table 8.1 - Structural components of theory (Gregor, 2006)

The conclusion from the overview presented in Table 8.1 is that there is sufficient reason to state that the theorizing on High Reliability genuinely can be called a theory since the structural components of theory are present in the way it is reconceptualized in this dissertation. This gives a first indication that HRT can be considered a scientific theory. This validates our choice to consistently use HRT – throughout this dissertation –as a body of constructs that explains high reliability in organizations.

2.6.2 Theory type

In the remainder of this section, we examine the theory type HRT represents. This examination will make clear where future enhancement of HRT could or should aim at.

Theory type	*Distinguishing attributes*	*HRT status*
Analysis	Says ‘what is’. The theory does not extend beyond analysis and description. No causal relationships among phenomena are specified and no predictions are made.	Causal relationships are specified and predictions are made.
Explanation	Says ‘what is’, ‘how’, ‘why’, ‘when’, ‘where’. The theory provides explanations but does not aim to predict with any precision. There are no testable propositions.	There are testable propositions.
Prediction	Says ‘what is’ and ‘what will be’. The theory provides predictions and has testable propositions but does not have well-developed justificatory causal explanations.	There are causal explanations.
Explanation and prediction	Says ‘what is’, ‘how’, ‘why’, ‘when’, ‘where’ and ‘what will be’. Provides predictions and has both testable propositions and causal explanations.	Testable hypotheses can be formulated.
Design and Action	Says ‘how to do something’. The theory gives explicit prescriptions (e.g., methods, techniques, principles of form and function) for constructing an artifact.	Modest evidence can be found on the presence of guidelines.

Table 8.2 - Testing HRT's theory type

Starting from these views on theory, we argue that HRT is a theory of the second-highest level, a theory for Explanation and Prediction. Nevertheless, this qualification is flattering for HRT since some remarks are in place. For instance, HRT does not explicitly say ‘why’ observations are made, which is a necessary condition for being capable of explaining. However, this shortcoming is compensated by its capacity to put forward testable propositions and causal explanations. We are strongly convinced that for answering this ‘why’ question an additional theoretical framework must be brought in, namely Loose Coupling Theory (Orton & Weick, 1990).

We assert that our research has contributed to the determination of HRT as a scientific theory. However, much more research must be done to perfect this determination and to provide it with an enhanced validity. In that respect, several questions arise. They can be grouped as follows (Gregor, 2006):

(1) *Domain* questions. What phenomena are of interest in the discipline? What are the core problems or topics of interest? What are the boundaries of the discipline?

(2) Structural or *ontological* questions. What is theory? How is this term understood in the discipline? Of what is theory composed? What forms do contributions to knowledge take? How is theory expressed? What types of claims or statements can be made? What types of questions are addressed?

(3) *Epistemological* questions. How is theory constructed? How can scientific knowledge be acquired? How is theory tested? What research methods can be used? What criteria are applied to judge the soundness and rigor of research methods?

(4) *Socio-political* questions. How is the disciplinary knowledge understood by stakeholders against the backdrop of human affairs? Where and by whom has theory been developed? What are the history and sociology of theory evolution? Are scholars in the discipline in general agreement about current theories or do profound differences of opinion exist? How is knowledge applied? Is the knowledge expected to be relevant and useful in a practical sense? Are there social, ethical or political issues associated with the use of the disciplinary knowledge?

3 Limitations of this Study

The research reported in this dissertation has four limitations that can serve as additional directions for future research. They are addressed next.

The results obtained in this thesis, using the ANOVA approach, are in themselves relatively discouraging since little significance is found when testing the hypotheses. This is especially so on the level of the one-way ANOVA testing. There are two explanations for this observation. First, little variance exists in the observations of the dependent and independent variables. Therefore, the probability of detecting significant interactions of independent variables, moderators and dependent variables using ANOVA is substantially reduced (Drazin & van de Ven, 1985, p. 535). Second, effects could not be easily tested due to the small sample size on the aggregated team level (Campion et al., 1996, p. 448). Despite the significant number of respondents in both cases (n=320 for the Bank, and n=124 for the NPP), once aggregated on team level, this was reduced to a considerably smaller number of teams in view of analysis of variance. Thus future research, aimed at replicating this research's findings, should strive to increase the number of teams under study so that the impact of mediating variables can be better studied. Obviously, the cost of such extensive study will likely be a critical factor.

Above we have argued that the fact that only two cases were studied is no impediment for the value of this thesis' conclusions. The internal validity is sufficiently covered for our purposes by the double case study approach. However, in view of ameliorating the external validity of our reconceptualized model, an extension to more cases is clearly beneficial.

A third limitation regards the fact that our survey needed to measure too much at the same time, which has lead to a relatively limited number of items per construct under study. Although we argue that this is necessary because of the exploratory and holistic vocation of our research, future research should consider remediating ths problem.

A last shortcoming of this research is the relative underexposure of SenseMaking. Although clearly present in our design and analysis, it has not been elaborated inf full. Future research could make an attempt of remediating this.

4 Future Research Directions

It is clear that a good deal of work lies ahead. Apart from the limitations and shortcomings in this study that should be remediated in future research, some additional directions become apparent.

4.1 Stronger research collaboration

HRO research is characterized by a tradition of collaboration. The interdisciplinarity of the Berkeley group for instance is characteristic in that respect (e.g. Rochlin et al., 1987). Although less prominent, also the collaboration between the Berkeley and Michigan scholars is in line with this observation (e.g. Weick & Roberts, 1993). What is lacking however is a structured inter-case analysis. This study has made a step in this direction, but the hope is real that by documenting such results and accumulating knowledge across and between organizational levels and populations, researchers can make significant advances in mid-range theory (Drazin & van de Ven, 1985, p. 536). If a series of studies at an industry level of analysis or for professional rather than bureaucratic subunits shows a different pattern of findings, then some systematic relationships between types (or levels) of organizations may become evident (Drazin & van de Ven, 1985, p. 536).

4.2 Loose Coupling Theory

During our research, we noted the following paradox: In spite of the fact that literature does not seem to mention something like a reliability equation or a recipe for reliability (stating what 'ingredients' and in which portions should be added to the organization's setting to ensure reliability), after the occurrence of a mishap, people seem to be always capable of "*pinpointing the exact moment when the balance tipped towards disaster*" (Sullivan & Beach, 2003). Therefore the question emerges whether it would not be possible to pre-determine the cut-off point at which an organization transfers from a reliable environment to one headed for disaster (Sullivan & Beach, 2003). Our research has not managed to find this recipe, it merely has found some of the ingredients and some indication on how the reliability cocktail could be created. We posit that Loose Coupling Theory, as reconceptualized by Orton and Weick (1990), is a proper framework for studying reliability. It offers an additional lens to better understand the reliability cocktail through the interrelation of dimensions like type, cause, effect, compensation and outcome of coupling. LCT may answer the 'why' question that cannot be answered by HRT alone.

A relevant question in that respect is then how HRT strategies influence the degree and shape of coupling and complexity. Therefore an examination into how one theory's independent variables affect the other theory's dependent variable (Rijpma, 1997a), and vice versa, is needed. In other words: What are the effects of complexity and tight-coupling on overall reliability? Or in Rijpma's words: "*And how do HROs' reliability-promoting strategies impinge on complexity and tight-coupling and, hence, on normal-accident proneness? How prone to normal accidents are organizations applying the reliability-enhancing strategies discerned by HRT?*" (Rijpma, 1997a, p. 16).

4.3 System Dynamics

Besides a more suitable theoretical framework in form of Loose Coupling Theory, also a stronger technique is needed to finetune what we have found in this study in order to determine more precisely the contextual and structural dimensions that have to be administered for reliability. System Dynamics is such a technique, and its further application in the domain looks promising. For instance, System Dynamics can help in challenging the Threat Rigidity thesis (Staw et al., 1981). Our findings indicate that there is reason to doubt this theory in its entirety. On the other hand, we have found evidence that Threat Rigidity sometimes is a valuable altenative for Threat Flexibility. System Dynamics is a suitable technique for dealing with such paradox.

4.4 Networked Reliability[76]

Another line of research would be the inter-organizational aspects of HRO. Inter-organizational high reliability is increasingly gaining importance, especially in the field of networked organizations like utility services (de Bruijne, 2006). Indeed, the particularity of this organization type magnifies the questions already raised in non-networked settings: can high reliability be accomplished by a network of organizations? What would this mean for the way they are coupled? What about the balance between efficiency and effectiveness? These questions are important because the transformation into network organizations means that traditional HROs tend to exchange their monolithic nature for one that is built out of many relations.

Both the sector of energy and finance are an excellent example of this tendency. The electricity market, for instance, is characterized by a liberalization of the composing parts (de Bruijne, 2006). Whereas a few years ago the production, distribution, transport and marketing of electricity was managed by one and the same firm, legislators under impulse of neo-liberalism have (artificially) split the industrial column and attributed the responsibility to different players. The business model was not the only aspect the 'electricians' had to change more or less over-night. The existing procedures, co-ordination and information processing mechanisms also had to be adapted to fit the new paradigm. It cannot be taken for granted that this is done in a way that can guarantee reliability in the longer run. It cannot be excluded that under the pressure of legislation and reasons of efficiency and shareholder-value creation merely lip service has been paid to reliability. Insight in complexity science however, learns that these changes *do* have consequences. The couplings between the 'anythings' (Weick, 1976, p. 5) have changed, and because it has not been mapped how and at what levels they have changed, the historic evidence of reliability cannot be extrapolated to the years to come.

The same logic and course of action applies to the sector of banking, where the search of economies of scale, market value and market share have lead to a conglomeration, nationally and internationally. The inter-organizational dimension becomes prevalent, especially when different (organization and/or national) cultures are in play or that processes and their quality show a different degree of maturity when comparing elements from the conglomeration. At best, this difference in speed will lead to some friction with loss of efficiency as a consequence. At worst, organizational reliability cannot be guaranteed conform the standards of the more mature processes. The potential result is not a leveling down of reliability, but its sheer destruction.

The key to solving the issue of inter-organizational high reliability might be a thorough elaboration of the concept of trust. Trust is an umbrella term for reliability for what links the constructs underlying HRT. It is a requisite for properties like Deference to Expertise, commitment ro resilience or Reluctance to Simplify. It is the lubricant for cross-boundary high reliability. In that respect, special attention should be paid to the design of information systems that can support the emergence and maintenance of trust between organizations (Ibrahim & Ribbers, 2006).

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1. Van de Walle,B., G.Van Den Eede, & W.Muhren (2009). Humanitarian Information Management and Systems. *Lecture Notes in Computer Science,* **5424**, 12-21.

2. Muhren,W., G.Van Den Eede, & B.Van de Walle (2009). Making Sense of Media Synchronicity in Humanitarian Crises. *IEEE Transactions on Professional Communication,* **52**(4),1-21.

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Appendices

Appendix A. Interview Protocol (Bank Case)

Z. Meta data	
Context	Are you familiar with the ITIL methodology? Do you know what Incident Management is? In what respect? How did you find out about it?
Context	In what way do you consider yourself related to continuous IT services? Since how long are you working as….? Current job-function?

A. People	
HR	Are there sometimes tensions between first, second and third line collaborators/services? Can these tensions cause sub optimality, danger even? Is there a divergence of goals between the stakeholders in the IM process?
HR	Is it easy to motivate personnel? Are collaborators complimented when they have successfully managed an incident? How is morale amongst IM service members?
HR	How is the promotion of collaborators of the process dealt with? How are collaborators rewarded? On what criteria is he/she judged? For working quickly or for working thoroughly?
HR	Is succession of key players guaranteed? Is there redundancy in people?
KM	Are collaborators stimulated to share information on solving problems/problems solved? Do we teach each other on IM?
KM	Is it possible to use competences of other specialists in the Bank if possible?
Training	Are people in the service sufficiently experienced for their job? Are all staff sufficiently trained? Why not? Do you know IM procedures are trained?
Training	To what extent do you think IM organization members are committed to resilience (ability to bounce back from errors and cope with unexpected events via improvisation) (HRT)?
Culture	Is there a shared mental model amongst the organization members on what it is all about (HRT)?

Culture	Is there 'requisite variety' (HRT)? Imagination, experiences, stories, simulations and symbolic representations here play an important role. A system that values these alternatives is more reliable, not only because one knows the system (and its possible failures) better but also befcause one has greater confidence in being able to handle failures because one knows others have been able to deal with them also (Weick 1987).
Culture	To what extent do you think IM organization members are preoccupied with failure? (HRT) "*HROs train their people to look for anomalies, recognize decoys, and, most importantly, to decouple systems when problems are discovered and then empower employees to act. HROs know that odd things can occur and want their people to be on the lookout for these odd or unusual things instead of assuming that they don't matter or are not important*" (Roberts 2001).
Culture	To what extent do you think IM organization members are reluctant to simplify interpretations (multiple perspectives) (HRT)?
Culture	Is there a 'shoot the messenger mentality'?
B. Process	
Incident	What is the most dramatic event you can recall during which business processes came to a halt? Can you give an example of an incident that caused a hindrance to your work? What is an incident to you? What determines something to be an incident? What determines priority? What are your ideas about informing people that an incident has occurred? Who should be responsible? Do you have examples of events that nearly caused interruption of daily processes? Which business interruptions occurred that in your view are related to automation/information technology? Which business interruptions do you expect to occur in future?
Incident	What is meant by recovery according to you? What data should be recovered first? What process should be recovered first? Could you tell in which order applications need to be restarted, in case a major disruption has occurred? What are your ideas about the organization recovery? What case could you construct in which recovery is successful? What case could you construct in which recovery is a failure?
Incident	What are the most critical IT services for your department? Which services should be provided in order to keep business running at a minimal level according to you? How should this level be determined? In what way does a minimal level of service relate to the goals of your department?

Incident	What is your opinion about how the continuity of IT services is managed? What aspects is a limitation in providing continuous IT service? What could be done according to you to improve continuity of IT services? On what criteria would you evaluate continuous service? What should IT know from the business units in order to improve the delivery of continuous service?
Incident	What is the impact to the business processes in case IT services come to a halt? How do you assess the importance of IT applications to function continuously? How do you assess the impact of business processes that are disrupted? How do you assess the financial impact of business processes that are disrupted? Which applications can automatically not function anymore due to the unavailability of other applications? In what way the point of time (within a 24h day) of an IT service disruption influences the organization? How would you determine the impact of a failure?
Incident	In what way your department is affected if other departments face discontinuity of IT services? What interdependencies between departments do you observe if the application of one department fails to function? For how long can you continue your business operations in case the processes in all other departments would have discontinued?
Incident	Can you give examples of a domino effect that culminated in a disaster?
Procedure	Are there procedures for IM? Are they known to you? Does everybody in the business know who to contact in case of an incident? Are they giving satisfaction? Are they always followed? Why not? Is it sometimes good that they are not followed?
Procedure	Are there procedures to alert for a threatening escalation of an incident? Is it possible that these procedures are ignored if they might disgrace a (group of) collaborator(s)? What happens if an incident seems to indicate that a mistake/failure/abuse/improper use has occurred? Is there the risk for a cover-up? Are all procedures always followed or are there by-passes possible? Is this always/sometimes/never good?
Procedure	Does IM provide in registration of incidents? Are these incidents traceable afterwards? Do they really get investigated or is it just an idle database? Is there a post-incident registration of the definitive incident category, impact code and cause (causing component). How do you get track of the incident management failures? Do you yourself register the failures concerning the IM process?
Procedure	How does the IM deal with waiting-lists for the registering of the calls/incidents? What happens to a *no-answer* (the user gave up trying to 'get in')? Is this a shared responsibility of the IM and user of just of the user alone? How is overburdening dealt with? How is it resolved ad-hoc? How is resolved on a longer term basis?

Procedure	If it seems during the handling of the incident that the number of impacted users is higher, how is this dealt with? Does the priority change?
Procedure	Is there a feedback mechanism to the user who reported the incident (on the projected time frame needed to solve the incident? Is there a feedback mechanism from the user to IM on the appreciation of the time frame?
Procedure	What kind of Key Reliability Indicators are in place in connection to the IM process?
Procedure	Has it happened that an incident was dealt with by an expert (elsewhere) in the organization, instead of the proper domain expert in the IM process? Were there conflicting solutions suggested? Which measures have been taken to avoid this?
Procedure	Do you know of situations were IM has worsened the situation? Was there something fundamentally wrong or was it just a coincidence? Do you know of situations where risk migrates when the introduction of a risk mitigation measure to address one problem in the system introduces other, unintended consequences in another part of the system.
Procedure	Are there aspects of the current procedures that are somewhat bureaucratic?
Procedure	Is there 'slack' built in the IM process (HRT)?
Procedure	Does the process of prioritizing incidents take into account SLAs? (quint.nl)
Procedure	Does Incident Management do a good job in identifying the priority of incidents? Did they get the impact right? Did they get the priority right? Is there a better way to get impact and/or priority right?
Procedure	Communication. What platforms are in place for briefing? What platforms are used for debriefing? How/Do you communicate changes in desired service levels and availability levels. When they increase? When they decrease? Has it ever happened that a service was restored conveniently but that you were not aware of this until you discovered by accident? Did you lose valuable time in the mean while? Do you have an opportunity to express your view on the incident? Did it occur that the solution which had been found was known to you/could have been suggested by you?
Meta	Are the stakeholders of IM questioned on a regular basis? How are the outcomes of these inquiries dealt with? Are they used for improving the IM process? Is there a double-loop learning mechanism, even when the incident does not lead to a 'problem'? Is there a double loop learning concerning IM. Are the procedures reviewed? Or is just the incident fixed?
Meta	If trends are spotted (by the Incident Managers), how are they implemented in the IT service management process?

Meta	Does the Incident Management Process Owners analyze the reliability of their service on a cost/benefit basis?
Meta	In a distributed system with limited physical oversight, the normal antidotes to human and organizational error—checks and balances, redundancy, and training—may be defeated by the size and scope of the system, or by subcultures which can develop in the system. How is internal control done? How can one be sure that procedures are followed? Are there sufficient checks and balances? Is there an equilibrium between responsibility and accountability?
Meta	Are there people in the IM process who still see the 'big picture'? How is the Sensitivity to Operations (seeing the big picture of operation in the moment)How is this big-picture composed (HRT)? The ultimate objective is the development of a culture of trust, which is so typical of HROs. HROs consistently communicate the big picture of what the organization seeks to do, and try to get everyone to communicate with each other about how they fit in the big picture (Roberts 2001). This is also called transactive memory (van Fenema 2003) and means that people know who does what in their (temporary) group, which in turn brings about stability.
Meta	Is the internal audit procedure effective in discovering risks? Are the recommendations of audit followed-up?
Meta	Is the best person always dealing with the problem? Or is there a mechanism to migrate the incident to the best-suited person? (migrating decision-making)
Meta	Is there a knowledge transfer from first line to second line collaborators in such a way that there is an increase in the success rate of solving incidents (quint.nl)?
Meta	How is Incident Management embedded in the other ITIL processes? How are the bridges between IM en Problem management? What about the information exchange?

C. Technology

Technology	Is the technology currently in use sufficient?
Technology	Is the technology compatible with other IS?
Technology	Is there redundancy in hardware and software?
Technology	Is the technology supportive of mindfulness (HRT)?
Procedure	Does the IM-tool simultaneously provide an adaptation of the Configuration Management Database (CMDB)?
Technology	Does the tool report adequate Management Information? Is this regularly checked with the management?

D. Environment	
Meta	What mechanisms are there to assure that the IM process is in line with external norms and legislation?
Structure	Are there elements in the IT organization, or the whole organization that are a hindrance to the way IM is operating?
Structure	On what basis are decisions for supplementary funding made? Have you had a restructuring of your services (downsizing, loss of personnel, cost-cutting)?
Structure	How would you describe the vision of management: long-term or short term? Do you have enough support from management or are they just pay lip service to you and your team (i.e. they are only happy when nothing happens but are not willing to do a preventive effort?) Have you tried to pull their attention to your problems?
Structure	Is there an under-specification of structures (organized anarchy via fluid decision-making) (HRT)?
Structure	Looking at crisis situations, Perrow (1999) recommends to put limits to the size of the parts of systems that could be stand-alone parts. He furthermore advises to "*link them through 'buses' – in the electrical sense – designed to buffer the disturbances in each*". The 'glue' between these components must be such that components still can range in diversity. This is with regard to management-styles, technologies, structures and decision processes. What is your opinion?
Culture	Does your organization have a safety culture? Would you describe the organization's culture as one fostering risk awareness/ Are there incentives for reporting on risk? Do you think the safety culture will still stand regardless of the leadership's personality and their concern with risk. Do you know who you should address in case you want to report a risk? Are you rewarded for a pro-active reporting on possible risks?
Culture	Hierarchies must allow for a broad and real delegation (Bigley 2001), with real delegation meaning the transfer of task, responsibility and authority.

Appendix B. Interview Protocol (NPP Case)

Z. Meta data	
Context	Are you familiar with the M&R methodology? Do you know what Incident Management is? In what respect? How did you find out about it?
Context	In what way do you consider yourself related to Maintenance & Repair (M&R) services? How long are you working as….? Current job-function?
A. People	
HR	Are there sometimes tensions people from different organizational levels (e.g. between you and your superior(s))? Can these tensions cause sub-optimality, danger even? Is there a divergence of goals between the stakeholders in the M&R process?
HR	Is it easy to motivate personnel? Are collaborators complimented when they have successfully managed an incident? How is morale amongst M&R service members?
HR	How is the promotion of collaborators of the process dealt with? How are collaborators rewarded? On what criteria is he/she judged for working quickly or for working thoroughly?
HR	Is succession of key players guaranteed? Is there redundancy in people?
KM	Are collaborators stimulated to share information on solving problems/ problems solved? Do we teach each other on M&R?
KM	Is it possible to use competences of other specialists in the plant if possible?
Training	Are people in the service sufficiently experienced for their job? Are all staff sufficiently trained? Why not? Do you know if M&R procedures are trained?
Training	To what extent do you think M&R organization members are committed to resilience (ability to bounce back from errors and cope with unexpected events via improvisation) (HRT)?
Culture	Is there a shared mental model amongst the organization members on what it is all about (HRT)?

Culture	Is there 'requisite variety' (HRT)? Imagination, experiences, stories, simulations and symbolic representations here play an important role. A system that values these alternatives is more reliable, not only because one knows the system (and its possible failures) better but also because one has greater confidence in being able to handle failures because one knows others have been able to deal with them also (Weick 1987).
Culture	To what extent do you think M&R organization members are preoccupied with failure? (HRT) “*HROs train their people to look for anomalies, recognize decoys, and, most importantly, to decouple systems when problems are discovered and then empower employees to act. HROs know that odd things can occur and want their people to be on the lookout for these odd or unusual things instead of assuming that they don't matter or are not important*” (Roberts 2001).
Culture	To what extent do you think M&R organization members are reluctant to simplify interpretations (multiple perspectives) (HRT)?
Culture	Is there a ‘shoot the messenger mentality’?
B. Process	
Incident	What is the most dramatic event you can recall during which business processes came to a halt? Can you give an example of an incident that caused a hindrance to your work? What is an incident to you? What determines something to be an incident? What determines priority? What are your ideas about informing people that an incident has occurred? Who should be responsible? Do you have examples of events that nearly caused interruption of daily processes? Which business interruptions occurred that in your view are related to automation/information technology? Which business interruptions do you expect to occur in future?
Incident	What is meant by recovery according to you? What process should be recovered first? Could you tell how to act in order to let the plant resume its operations, in case a major disruption has occurred? What are your ideas about the organization recovery? What case could you construct in which recovery is successful? What case could you construct in which recovery is a failure?
Incident	What are the most critical (production) services for your department? Which services should be provided in order to keep business running at a minimal level according to you? How should this level be determined? In what way does a minimal level of service relate to the goals of your department?

Incident	What is your opinion about how the continuity of plant operation is managed? What aspect is a limitation in providing continuous plant operation? What could be done according to you to improve continuity of plant operation? On what criteria would you evaluate continuous service?
Incident	What is the impact to the business processes in case (production) services come to a halt? How do you assess the importance of production applications to function continuously? How do you assess the impact of business processes that are disrupted? How do you assess the financial impact of business processes that are disrupted? Which applications can automatically not function anymore due to the unavailability of other applications? In what way the point of time (within a 24h day) of an service disruption influences the organization? How would you determine the impact of a failure?
Incident	In what way your department is affected if other departments face discontinuity of services? What interdependencies between departments do you observe if the application of one department fails to function? For how long can you continue your business operations in case the processes in all other departments would have discontinued?
Incident	Can you give examples of a domino effect that culminated in an incident?
Procedure	Are there procedures for M&R? Are they known to you? Does everybody in the business know who to contact in case of an incident? Are they giving satisfaction? Are they always followed? Why not? Is it sometimes good that they are not followed?
Procedure	Are there procedures to alert for a threatening escalation of an incident? Is it possible that these procedures are ignored if they might disgrace a (group of) collaborator(s)? What happens if an incident seems to indicate that a mistake/failure/abuse/improper use has occurred? Is there the risk for a cover-up? Are all procedures always followed or are there by-passes possible? Is this always/sometimes/never good?
Procedure	Does M&R provide in registration of incidents? Are these incidents traceable afterwards? Do they really get investigated or is it just an idle database? Is there a post-incident registration of the definitive incident category, impact code and cause (causing component). How do you get track of the incident management failures? Do you yourself register the failures concerning the M&R process?
Procedure	How does the M&R deal with waiting-lists for the registering of the calls/incidents? What happens to a no-answer (the user gave up trying to 'get in')? Is this a shared responsibility of the M&R and user of just of the user alone? How is overburdening dealt with? How is it resolved ad-hoc? How is resolved on a longer term basis?

Procedure	If it seems during the handling of the incident that the impact on operations or plant/personnel safety changes? Does the priority change?
Procedure	Is there a feedback mechanism to the user who reported the incident (on the projected time frame needed to solve the incident? Is there a feedback mechanism from the user to M&R on the appreciation of the time frame?
Procedure	What kind of Key Reliability Indicators are in place in connection to the M&R process?
Procedure	Has it happened that an incident was dealt with by an expert (elsewhere) in the organization, instead of the proper domain expert in the M&R process? Were there conflicting solutions suggested? Which measures have been taken to avoid this?
Procedure	Do you know of situations where M&R has worsened the situation? Was there something fundamentally wrong or was it just a coincidence? Do you know of situations where risk migrates when the introduction of a risk mitigation measure to address one problem in the system introduces other, unintended consequences in another part of the system?
Procedure	Are there aspects of the current procedures that are somewhat bureaucratic?
Procedure	Is there 'slack' built in the M&R process (HRT)?
Procedure	Does the process of prioritizing incidents take into account SLAs? (quint.nl)
Procedure	Does Incident Management do a good job in identifying the priority of incidents? Did they get the impact right? Did they get the priority right? Is there a better way to get impact and/or priority right?
Procedure	Communication. What platforms are in place for briefing? What platforms are used for debriefing? (How/Do you communicate changes in desired service levels and availability levels. When they increase? When they decrease?) Has it ever happened that a service was restored conveniently but that you were not aware of this until you discovered by accident? Did you lose valuable time in the meanwhile? Do you have an opportunity to express your view on the incident? Did it occur that the solution which had been found was known to you/could have been suggested by you?
Meta	Are the stakeholders of M&R questioned on a regular basis? How are the outcomes of these inquiries dealt with? Are they used for improving the M&R process? Is there a double-loop learning mechanism, even when the incident does not lead to a 'problem'? Is there a double loop learning concerning M&R. Are the procedures reviewed? Or is just the incident fixed?
Meta	If trends are spotted (by the M&R Managers), how are they implemented in the M&R process?

Meta	Does the Incident Management Process Owners analyze the reliability of their service on a cost/benefit basis?
Meta	In a distributed system with limited physical oversight, the normal antidotes to human and organizational error—checks and balances, redundancy, and training—may be defeated by the size and scope of the system, or by subcultures which can develop in the system. How is internal control done? How can one be sure that procedures are followed? Are there sufficient checks and balances? Is there an equilibrium between responsibility and accountability?
Meta	Are there people in the M&R process who still see the 'big picture'? How is the Sensitivity to Operations (seeing the big picture of operation in the moment)How is this big-picture composed (HRT)? The ultimate objective is the development of a culture of trust, which is so typical of HROs. HROs consistently communicate the big picture of what the organization seeks to do, and try to get everyone to communicate with each other about how they fit in the big picture (Roberts 2001). This is also called transactive memory (van Fenema 2003) and means that people know who does what in their (temporary) group, which in turn brings about stability.
Meta	Is the internal audit procedure effective in discovering risks? Are the recommendations of audit followed-up?
Meta	Is the best person always dealing with the problem? Or is there a mechanism to migrate the incident to the best-suited person? (migrating decision-making)
Meta	Is there a knowledge transfer from first line to second line collaborators in such a way that there is an increase in the success rate of solving incidents (quint.nl)?
Meta	How is Incident Management embedded in the other NPP processes (raakpunten)? How are the bridges between M&R en Problem management? What about the information exchange?
C. Technology	
Technology	Is the technology currently in use sufficient?
Technology	Is the technology compatible with other IS?
Technology	Is there redundancy in hardware and software?
Technology	Is the technology supportive of mindfulness (HRT)?
Procedure	Does the M&R-tool simultaneously provide an adaptation of the Configuration Management Database (CMDB)?
Technology	Does the tool report adequate Management Information? Is this regularly

	checked with the management?
D. Environment	
Meta	What mechanisms are there to assure that the M&R process is in line with external norms and legislation?
Structure	Are there elements in the NPP organization, or the whole mother holding that are a hindrance to the way M&R is operating?
Structure	On what basis are decisions for supplementary funding made? Have you had a restructuring of your services (downsizing, loss of personnel, cost-cutting)?
Structure	How would you describe the vision of management: long-term or short term? Do you have enough support from management or are they just there to pay lip service to you and your team (i.e. they are only happy when nothing happens but are not willing to do a preventive effort?) Have you tried to pull their attention to your problems?
Structure	Is there an under-specification of structures (organized anarchy via fluid decision-making) (HRT)?
Structure	Looking at crisis situations, Perrow (1999) recommends to put limits to the size of the parts of systems that could be stand-alone parts. He furthermore advises to "*link them through 'buses' – in the electrical sense – designed to buffer the disturbances in each*". The 'glue' between these components must be such that components still can range in diversity. This is with regard to management-styles, technologies, structures and decision processes. What is your opinion?
Culture	Does your organization have a safety culture? Would you describe the organization's culture as one fostering risk awareness/ Are there incentives for reporting on risk? Do you think the safety culture will still stand regardless of the leadership's personality and their concern with risk. Do you know who you should address in case you want to report a risk? Are you rewarded for a pro-active reporting on possible risks?
Culture	Hierarchies must allow for a broad and real delegation (Bigley 2001), with real delegation meaning the transfer of task, responsibility and authority.

Appendix C. Testing the A Priori Conceptual Model

13.5	When problems arise, I know where/how I can reach a decision-maker.
14.4	When handling an incident I take into account the consequences for the organization as a whole.
20.5	There is consensus amongst the members of our team on HOW things could go wrong with crucial systems.
24.2	I am familiar with processes (business or IT) that are strictly speaking outside the scope of my job.

Table 0.1 - A Priori Survey Items for Sensitivity to Operations

15.4	When the unexpected happens, I investigate why things did not go as expected.
19.5	In our team we take into account each other's opinion regarding the handling of incidents.
19.6	In our team we spend a lot of time on incident analysis in order to better understand future incidents.
20.1	In our team we listen carefully to each other; it is exceptional that an opinion is not listened to.
20.2	In our team people demonstrate trust for each other.
24.1	I am encouraged to ask questions.

Table 0.2 - A Priori Survey Items for Reluctance to Simplify

13.6	I dispose of a number of informal contacts that I use to deal with problems.
17.2	When handling an incident of priority 1 or 2 it is easy to get access to supplementary resources.
19.2	In our team we learn from our mistakes.
22.4	I have sufficient training and experience to handle incidents.
23.2	My management mobilizes supplementary people whenever the workload of our teams becomes excessive.

Table 0.3 - A Priori Survey Items for Commitment to Resilience

15.1	I consider near-misses as an indication of potential danger.
15.2	I handle near-misses and mistakes as information on the reliability of our system.
15.3	I tend to report mistakes that could have important consequences, even when no-one has noticed them.

19.1	When the unexpected happens, we report in our team what has happend prior to the incident.
20.4	There is consensus amongst the members of our team on WHAT should not go wrong with crucial systems.
23.4	I feel free to speak to superiors about difficulties in my work situation.

Table 0.4 - A Priori Survey Items for Preoccupation with Failure

14.1	When something exceptional happens, I know who has the expertise to respond.
17.1	When handling a severe incident (priority 1 or 2) it is easy to get hold of all necessary information.
19.4	As a team we feel ownership for the incident untill it is solved.
20.3	When handling a severe incident (priority 1 or 2) we consult other team members.
22.5	When necessary, superiors let subordinates with more technical expertise make decisions.

Table 0.5 - A Priori Survey Items for Deference to Expertise

The exploratory factor analysis based on these items resulted in the rotated component matrix shown in Table 0.6.

	1	2	3	4	5	6	7	8
19.6 In our team we spend a lot of time on incident analysis in order to better understand future incidents.	0,735879	0,059589	-0,00587	0,105499	0,114218	0,164073	0,093717	-0,08817
19.2 In our team we learn from our mistakes.	0,71688	0,258561	0,157433	0,062689	0,054365	0,063477	0,055555	0,043863
19.1 When the unexpected happens, we report in our team what has happend prior to the incident.	0,67914	0,256382	-0,04072	0,193936	-0,0395	0,020641	0,206143	-0,02806
19.4 As a team we feel ownership for the incident untill it is solved.	0,567189	-0,02391	0,382932	0,085644	0,260354	0,005678	-0,02678	0,072606
19.5 In our team we take into account each other's opinion regarding the handling of incidents.	0,510133	0,242375	0,331973	0,042018	0,347693	0,092082	-0,15197	0,156172
20.1 In our team we listen carefully to each other; it is exceptional that an opinion is not listened to.	0,468758	0,383378	0,198256	-0,03959	0,340996	0,036005	-0,2596	0,250464
20.2 In our team we trust each other.	0,453692	0,382631	0,246712	0,001942	0,260617	0,033632	-0,28706	0,272172
20.5 There is consensus amongst the members of our team on HOW things could go wrong with crucial systems.	0,206431	0,818518	-0,04997	0,152929	0,11828	0,129859	0,087403	0,016138
20.4 There is consensus amongst the members of our team on WHAT should not go wrong with crucial systems.	0,243208	0,81815	0,042542	0,083918	0,042218	0,075375	0,122969	-0,03652
20.3 When handling a severe incident (priority 1 or 2) we consult other team members.	0,265215	0,423159	0,192173	0,351273	0,217668	-0,18997	-0,11183	0,026635
15.3 I tend to report mistakes that could have important consequences, even when no-one has noticed them.	0,13097	-0,10581	0,75672	-0,06393	0,042138	0,092235	0,120929	-0,01963
14.4 When handling an incident I take into account the consequences for the organization as a whole.	0,032041	0,199192	0,720781	0,078698	-0,1796	0,089565	0,037373	0,026071
15.4 When the unexpected happens, I investigate why things did not go as expected.	0,147736	0,030801	0,612825	0,08907	0,098257	0,031717	0,208606	-0,07893
17.2 When handling an incident of priority 1 or 2 it is easy to get access to supplementary resources.	0,211247	0,090249	0,019004	0,817586	0,0797	0,006448	0,017315	-0,0822
17.1 When handling a severe incident (priority 1 or 2) it is easy to get hold of all necessary information.	0,216511	0,047481	-0,1243	0,57188	0,009538	0,212213	-0,25045	-0,14327
13.5 When problems arise, I know where/how I can reach a decision-maker.	-0,06747	0,238966	0,231424	0,540783	0,157388	0,22604	-0,08116	0,147054

22.5 When necessary, superiors let subordinates with more technical expertise make decisions.	0,064237	0,07354	-0,02696	0,531077	0,385313	-0,07909	0,237974	0,283001
14.1 When something exceptional happens, I know who has the expertise to respond.	-0,04967	-0,0161	0,149353	0,509214	0,040088	0,453774	0,227097	0,161641
23.2 My management mobilizes supplementary people whenever the workload of our teams becomes excessive.	0,078556	-0,07326	-0,11229	0,205183	0,731951	-0,00243	-0,06049	-0,07275
23.4 I feel free to speak to superiors about difficulties in my work situation.	0,151568	0,203155	0,129797	0,072934	0,659	0,285572	0,012822	0,111777
24.1 I am encouraged to ask questions.	0,23007	0,348075	0,044337	0,045238	0,631223	0,125209	0,088679	-0,26067
24.2 I am familiar with processes (business or IT) that are strictly speaking outside the scope of my job.	0,119371	0,12575	0,041226	0,024054	0,104514	0,752709	0,013768	-0,06857
22.4 I have sufficient training and experience to handle incidents.	0,116823	0,010907	0,114498	0,193012	0,102237	0,711112	0,005702	0,235024
15.2 I handle near-misses and mistakes as information on the reliability of our system.	0,158236	0,186734	0,187531	-0,05455	-0,11068	0,157592	0,738563	0,039766
15.1 I consider near-misses as an indication of potential danger.	0,025914	-0,03546	0,420013	0,011217	0,154931	-0,0922	0,614604	0,161293
13.6 I dispose of a number of informal contacts that I use to deal with problems.	0,045614	6,63E-05	-0,06127	0,030525	-0,08739	0,146334	0,122894	0,847598
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 8 iterations.								

Table 0.6 - Rotated Component Matrix of HRT items from Literature

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,828
Bartlett's Test of Sphericity	Approx. Chi-Square	1889,098
	Df	325
	Sig.	,000

Table 0.7 - KMO and Bartlett's Test for a priori HRT Variables (Bank)

Table 0.8 shows that the total variance explanation criterion of 60% is met.

Component	*Initial Eigenvalues*			*Extraction Sums of Squared Loadings*			*Rotation Sums of Squared Loadings*		
	Total	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*
1	6,202	23,853	23,853	6,202	23,853	23,853	2,977	11,449	11,449
2	2,205	8,482	32,335	2,205	8,482	32,335	2,352	9,047	20,495
3	1,917	7,372	39,707	1,917	7,372	39,707	2,246	8,640	29,135
4	1,410	5,422	45,129	1,410	5,422	45,129	2,156	8,292	37,428
5	1,256	4,832	49,961	1,256	4,832	49,961	2,112	8,124	45,552
6	1,113	4,280	54,241	1,113	4,280	54,241	1,651	6,350	51,902
7	1,061	4,079	58,320	1,061	4,079	58,320	1,451	5,580	57,482
8	1,015	3,906	62,226	1,015	3,906	62,226	1,233	4,744	62,226
9	,865	3,326	65,552						
10	,850	3,268	68,820						
11	,834	3,209	72,029						
12	,762	2,930	74,959						
13	,708	2,722	77,680						
14	,637	2,448	80,129						
15	,611	2,348	82,477						

16	,586	2,255	84,732							
17	,550	2,117	86,849							
18	,514	1,977	88,826							
19	,478	1,837	90,663							
20	,438	1,684	92,347							
21	,421	1,620	93,967							
22	,378	1,452	95,419							
23	,353	1,356	96,775							
24	,329	1,265	98,040							
25	,268	1,030	99,070							
26	,242	,930	100,000							

Table 0.8 - Total Variance Explained of A Priori Factor Analysis for HRT items

Appendix D. Descriptive Respondent Statistics (Bank Case)

	N	Min.	Max.	Mean	Std. Dev
1. Are you an internal or external employee?	320	1	2	1,26	,439
2. What is your gender?	318	1	2	1,22	,417
4. At what physical location do you work?	311	1	10	4,03	2,646
5. How many years of experience with incident handling do you have?	294	,0	30,0	6,901	5,6118
6. What team are you a member of? In case you are a member of more than one team, indicate that team where you feel most part of.	315	2	69	34,79	20,972
Team Size	296	3	36	13,86	7,369
Number of team members	320	1	19	8,22	4,687
7. What department are you a member of?	316	2	29	10,00	6,530
8. How much of your time (%) do you spend in handling incidents?	309	0	100	21,22	19,907
9. How much (%) do you rely on Peregrine for the registration/coordination/escalation/closing of an incident?	311	0	100	83,15	26,441
10. How much (%) do you register allmost immediately the necessary data in Peregrine?	306	0	100	69,27	28,464
11.1 face-to-face communication	246	1	80	16,65	14,818
11.2 telephone/cell phone	314	3	95	31,82	18,316
11.3 e-mail	300	1	75	21,29	12,885
11.4 Peregrine	309	1	100	35,42	24,220
11.5 Other means of communication	59	1	20	6,46	3,914
Ratio nondedicated vs dedicated	232	,18	99,00	5,6850	10,34781
Ratio voice vs nonvoice	232	,05	13,29	1,4302	1,68983
13.1 I feel emotionally involved when handling incidents. The work does not let go.	306	1	5	3,46	1,043

13.2 I consider the adequate handling of incidents as a matter of honour.	309	1	5	4,13	,764
13.3 When handling incidents I call similar prior incidents to mind.	312	2	5	4,27	,639
13.4 When making decisions/taking action I take into account the possible reaction of my colleagues.	307	1	5	3,79	,896
13.5 When problems arise, I know where/how I can reach a decision-maker.	314	1	5	4,13	,677
13.6 I dispose of a number of informal contacts that I use to deal with problems.	310	1	5	4,03	,710
13.7 When handling an incident I deal with it incrementally. I adjust my actions.	311	1	5	4,01	,617
14.1 When something exceptional happens, I know who has the expertise to respond.	313	1	5	3,98	,655
14.2 I sometimes rely on improvisation to find a solution.	311	1	5	3,39	,884
14.3 To perform the job, I sometimes defer from procedure.	309	1	5	3,54	,847
14.4 When handling an incident I take into account the consequences for the organization as a whole.	311	2	5	4,29	,567
14.5 When I handle an incident, I sometimes rely on information that is (or does not need to be) 100% certain.	309	1	5	2,83	,965
14.6 When I make decisions in the handling of incidents, my approach is rational rather than intuitive.	311	1	5	3,81	,750
15.1 I consider near-misses as an indication of potential danger.	296	1	5	3,92	,666
15.2 I handle near-misses and mistakes as information on the reliability of our system.	297	1	5	3,88	,648
15.3 I tend to report mistakes that could have important consequences, even when no-one has noticed them.	313	2	5	4,38	,577
15.4 When the unexpected happens, I investigate why things did not go as expected.	310	2	5	4,24	,599

17.1 When handling a severe incident (priority 1 or 2) it is easy to get hold of all necessary information.	290	1	5	3,26	,853
17.2 When handling an incident of priority 1 or 2 it is easy to get access to supplementary resources.	289	1	5	3,79	,742
19.1 When the unexpected happens, we report in our team what has happend prior to the incident.	311	1	5	3,85	,773
19.2 In our team we learn from our mistakes.	314	2	5	4,17	,577
19.3 I feel good in our team.	316	1	5	4,22	,760
19.4 As a team we feel ownership for the incident untill it is solved.	313	2	5	4,14	,653
19.5 In our team we take into account each other's opinion regarding the handling of incidents.	313	2	5	4,12	,587
19.6 In our team we spend a lot of time on incident analysis in order to better understand future incidents.	309	1	5	3,51	,896
20.1 In our team we listen carefully to each other; it is exceptional that an opinion is not listened to.	312	2	5	4,05	,657
20.2 In our team we trust each other.	313	2	5	4,11	,631
20.3 When handling a severe incident (priority 1 or 2) we consult other team members.	296	2	5	4,20	,676
20.4 There is consensus amongst the members of our team on WHAT should not go wrong with crucial systems.	300	2	5	3,96	,640
20.5 There is consensus amongst the members of our team on HOW things could go wrong with crucial systems.	297	2	5	3,76	,638
20.6 Because of pressure (time-pressure or other) our team often deviates from procedure.	308	1	5	2,92	,924
22.1 I feel a lot of pressure to save on costs and time.	313	1	5	3,58	,910
22.2 I have a lot of freedom when handling incidents.	307	1	5	3,55	,851
22.3 I feel I receive challenging assingments.	312	1	5	3,46	,777
22.4 I have sufficient training and experience to handle incidents.	308	1	5	3,82	,792

22.5 When necessary, superiors let subordinates with more technical expertise make decisions.	300	1	5	3,79	,750
23.1 [COMPANY]-ICT is exposed to many dangers/threats.	309	2	5	3,17	,784
23.2 My management mobilizes supplementary people whenever the workload of our teams becomes excessive.	308	1	5	3,20	,899
23.3 In [COMPANY]-ICT it is easy to ask for help.	314	1	5	3,63	,667
23.4 I feel free to speak to superiors about difficulties in my work situation.	313	1	5	3,85	,732
24.1 I am encouraged to ask questions.	317	1	5	3,62	,699
24.2 I am familiar with processes (business or IT) that are strictly speaking outside the scope of my job.	312	1	5	3,31	,823
24.3 I am expected to do my job in a certain manner without deviating from procedure.	315	1	5	3,34	,792
24.4 I often work under high productivity pressure (time, costs).	314	1	5	3,57	,829

Appendix E. Descriptive Respondent Statistics (NPP Case)

	N	*Min.*	*Max*	*Mean*	*Std. Dev*
0. ID	124	1	128	63,36	37,045
1. Are you an internal or external employee?	124	1	2	1,02	,154
2. What is your gender?	124	1	2	1,03	,177
3.1. Are you a manager?	124	1	2	1,27	,444
3.2. Which personnel category do you belong to?	124	1	3	1,73	,515
4. What is your physical work location?	124	1	6	2,60	1,715
5. How many years of experience do you have in handling incidents?	122	0	36	10,98	8,956
Team ID	124	1	99999	827,08	8978,312
N BREAK	124	1	11	5,18	3,001
Team Size	119	2	70	23,54	22,711
Participation	119	,11	1,00	,3500	,21632
7.1. How much (%) do you use SAP history for the work preparation?	108	0	100	35,77	30,501
7.2. From how many different people do you get input (conversation, telephone, e-mail, notifications)?	97	0	1000	183,97	276,387
Q72LIKERT	97	1	5	2,86	1,436
8. How many of the cases (%) do you notice a procedure needs to be adjusted?	111	0	80	14,69	16,591
9. In how many of the cases (%) do you take action to change the procedure?	114	0	100	77,57	33,624
10. In how many of the cases (%) do you timely register the necessary data in SAP?	87	0	100	66,33	33,329
11.1 face-to-face communication	120	,00	1,00	,2787	,25701
11.2 telephone/cell phone	120	,00	,75	,1972	,14638
11.3 e-mail	120	,00	,80	,2045	,16822
11.4 SAP	120	,00	1,00	,3004	,27084
11.5 Other means of communication	120	,00	,30	,0192	,05422

Ratio nondedicated vs dedicated	104	,00	24,00	4,8262	5,64270
Ratio voice vs nonvoice	113	,00	9,00	1,4269	1,82780
Ratio face vs distance	114	,00	4,00	,5241	,84234
13.1 I feel emotionally involved with my work. The work does not let go.	123	1	5	3,77	,885
13.2 I consider the adequate handling of incidents as a matter of honour.	124	3	5	4,44	,615
13.3 When handling incidents I call similar prior incidents to mind.	122	1	5	4,11	,695
13.4 When making decisions/taking action I take into account the possible reaction of my colleagues.	124	1	5	3,75	,823
13.5 When problems arise, I know where/how I can reach a decision-maker.	121	1	5	4,10	,735
13.6 I dispose of a number of informal contacts that I use to deal with problems.	120	1	5	3,51	,935
13.7 When handling an incident I deal with it incrementally. I adjust my actions.	124	2	5	4,01	,591
14.1 When something exceptional happens, I know who has the expertise to respond.	124	1	5	3,90	,748
14.2 I sometimes rely on improvisation to find a solution.	121	1	5	2,84	1,103
14.3 To perform the job, I sometimes defer from procedure.	121	1	5	3,08	,988
14.4 When handling an incident I take into account the consequences for the organization as a whole.	123	3	5	4,11	,603
14.5 When I handle an incident, I sometimes rely on information that is (or does not need to be) 100% certain.	121	1	5	2,44	,999
14.6 When I make decisions in the handling of incidents, my approach is rational rather than intuitive.	124	2	5	3,86	,702
Q146INV	124	1	4	2,14	,702
15.1 I consider near-misses as an indication of potential danger.	122	2	5	4,30	,628
15.2 I handle near-misses and mistakes as information on the reliability of our system.	123	1	5	4,24	,669
15.3 I tend to report mistakes that could have important	123	3	5	4,48	,548

consequences, even when no-one has noticed them.					
15.4 When the unexpected happens, I investigate why things did not go as expected.	121	3	5	4,32	,520
17.1 When handling a severe incident (priority 0) it is easy to get hold of all necessary information.	100	1	5	3,23	,930
17.2 When handling an incident of priority 1 or 2 it is easy to get access to supplementary resources.	98	1	5	3,24	,975
19.1 When the unexpected happens, we report in our team what has happend prior to the incident.	116	2	5	4,08	,592
19.2 In our team we learn from our mistakes.	119	3	5	4,30	,545
19.3 I feel good in our team.	120	2	5	4,32	,661
19.4 As a team we feel ownership for the incident untill it is solved.	119	2	5	4,22	,666
19.5 In our team we take into account each other's opinion regarding the handling of incidents.	119	3	5	4,23	,559
19.6 In our team we spend a lot of time on incident analysis in order to better understand future incidents.	119	1	5	3,66	,906
20.1 In our team we listen carefully to each other; it is exceptional that an opinion is not listened to.	119	3	5	4,13	,566
20.2 In our team we trust each other.	119	2	5	4,19	,601
20.3 When handling an urgent incident (priority 0) we consult other team members.	98	2	5	3,62	,767
20.4 I know which assignments are crucial.	119	2	5	4,19	,492
20.5 There is consensus amongst the members of our team on *HOW* things could go wrong with crucial systems.	115	3	5	4,13	,522
20.6 There is consensus amongst the members of our team on *WHAT* could go wrong with crucial systems.	115	1	5	3,92	,677
20.7 Because of pressure (time-pressure or other) our team often deviates from procedure.	117	1	5	2,08	,892
22.1 I feel a lot of pressure to save on costs and time.	121	1	5	2,96	,934
22.2 I have a lot of freedom when handling incidents.	124	1	5	3,62	,907
22.3 I feel I receive challenging assingments.	124	2	5	3,64	,725
22.4 I have sufficient training and experience to handle incidents.	123	2	5	3,88	,696
22.5 When necessary, superiors let subordinates with more technical expertise make decisions.	121	1	5	3,63	,776

23.1 [COMPANY] is exposed to many dangers/threats.	123	1	5	3,03	,999
23.2 My management mobilizes supplementary people whenever the workload of our teams becomes excessive.	119	1	5	2,87	,962
23.3 In [COMPANY] it is easy to ask for help.	124	2	5	3,56	,735
23.4 I feel free to speak to superiors about difficulties in my work situation.	124	2	5	4,08	,645
24.1 I am encouraged to ask questions.	124	2	5	3,65	,735
24.2 I am familiar with processes that are strictly speaking outside the scope of my job.	123	1	5	3,37	,716
24.3 I am expected to do my job in a certain manner without deviating from procedure.	124	2	5	3,76	,820
Q243INV	124	1	4	2,24	,820
24.4 I often work under high productivity pressure (time, costs).	124	2	5	3,56	,735
Q244INV	124	1	4	2,44	,735
25. When we do not dispose of a particular type of knowledge/information, we know who in our organization can help us.	123	1	5	3,72	,659
26. I feel free to contact people outside of our team about difficulties in my work.	122	2	5	3,87	,692
27. The interaction between the different steps in the maintenance & repair process runs smoothly.	116	1	5	3,26	,825
28. The order in which you perform tasks that are necessary to solve a problem can vary.	123	1	5	3,67	,719
29. The Maintenance & Repair process has built-in buffers/security in case something goes wrong or makes a mistake.	118	1	5	3,32	,738
Q29INV	118	1	5	2,68	,738
30. The systems and processes I am responsible for, have no secrets for me.	122	1	5	3,07	,864
Q30INV	122	1	5	2,93	,864
31. The systems and processes in our work, can lead to unpredictable reactions.	122	1	5	3,02	,848
32. The systems and processes in our work are tightly coupled.	123	2	5	3,84	,751
Q32INV	123	1	4	2,16	,751
33. The information that is needed for my work can	120	3	5	4,14	,612

come from many different sources.					
1. Are you an internal or external employee?	124	1,00	1,50	1,0242	,09065
2. What is your gender?	124	1,00	1,50	1,0323	,09687
3.1. Are you a manager?	124	1,00	2,00	1,2661	,31009
3.2. What personnel category do you belong to?	124	1,00	3,00	1,7258	,35369
4. What is your physical work location?	124	1,00	6,00	2,5968	1,45670
5. How many years of experience do you have regarding the Maintenance & Repair process?	124	,53	26,00	10,9472	5,96062
7.1. How much (%) do you use SAP history for the work preparation?	122	1,00	90,00	34,1393	20,63094
7.2. From how many different people do you get input (conversation, telephone, e-mail, notifications)?	120	4,00	800,00	163,6472	173,56193
Q72LIKERT	120	1,00	5,00	2,7789	,91344
8. How many of the cases (%) do you notice a procedure needs to be adjusted?	122	2,00	51,00	13,8926	9,14959
9. In how many of the cases (%) do you take action to change the procedure?	123	5,00	100,00	76,6935	22,04407
10. In how many of the cases (%) do you timely register the necessary data in SAP?	121	5,00	100,00	66,3525	19,08023
11.1 face-to-face communication	124	,00	82,50	40,2731	20,28722
11.2 telephone/cell phone	124	3,37	90,00	29,6727	15,18975
11.3 e-mail	124	,00	80,00	30,9659	16,08417
11.4 SAP	124	5,00	100,00	39,0147	14,97312
11.5 Other means of communication	124	,00	52,50	3,7132	8,72586
Ratio nondedicated vs dedicated	124	,00	24,00	5,0142	3,94115
Ratio voice vs nonvoice	124	,00	5,67	1,4073	1,04594
Ratio face vs distance	124	,00	3,00	,5245	,42945
13.1 I feel emotionally involved with my work. The work does not let go.	124	2,00	4,50	3,7742	,43845

13.2 I consider the adequate handling of incidents as a matter of honour.	124	3,00	5,00	4,4355	,35816
13.3 When handling incidents I call similar prior incidents to mind.	124	3,00	5,00	4,1169	,33956
13.4 When making decisions/taking action I take into account the possible reaction of my colleagues.	124	1,00	5,00	3,7500	,44921
13.5 When problems arise, I know where/how I can reach a decision-maker.	124	2,00	5,00	4,1109	,36546
13.6 I dispose of a number of informal contacts that I use to deal with problems.	123	2,57	5,00	3,5158	,60604
13.7 When handling an incident I deal with it incrementally. I adjust my actions.	124	3,00	5,00	4,0081	,30932
14.1 When something exceptional happens, I know who has the expertise to respond.	124	3,00	5,00	3,9032	,36633
14.2 I sometimes rely on improvisation to find a solution.	124	1,00	5,00	2,8293	,58849
14.3 To perform the job, I sometimes defer from procedure.	124	1,00	4,00	3,0789	,51652
14.4 When handling an incident I take into account the consequences for the organization as a whole.	124	3,00	5,00	4,1129	,28176
14.5 When I handle an incident, I sometimes rely on information that is (or does not need to be) 100% certain.	123	1,00	4,00	2,4295	,59763
14.6 When I make decisions in the handling of incidents, my approach is rational rather than intuitive.	124	2,75	5,00	3,8629	,42229
Q146INV	124	1,00	3,25	2,1371	,42229
15.1 I consider near-misses as an indication of potential danger.	124	3,33	5,00	4,2979	,41311
15.2 I handle near-misses and mistakes as information on the reliability of our system.	124	3,00	5,00	4,2460	,37242
15.3 I tend to report mistakes that could have important consequences, even when no-one has noticed them.	123	3,67	5,00	4,4797	,29139
15.4 When the unexpected happens, I investigate why things did not go as expected.	124	3,67	5,00	4,3246	,29137
17.1 When handling a severe incident (priority 0) it is easy to get hold of all necessary information.	122	2,00	5,00	3,2447	,60304
17.2 When handling an incident of priority 1 or 2 it is easy to get access to supplementary resources.	121	2,00	5,00	3,2544	,53644

19.1 When the unexpected happens, we report in our team what has happend prior to the incident.	123	3,00	5,00	4,0724	,34190
19.2 In our team we learn from our mistakes.	123	3,67	5,00	4,2977	,30407
19.3 I feel good in our team.	123	3,00	5,00	4,3221	,38361
19.4 As a team we feel ownership for the incident untill it is solved.	123	3,00	5,00	4,2302	,35146
19.5 In our team we take into account each other's opinion regarding the handling of incidents.	123	3,00	5,00	4,2359	,38420
19.6 In our team we spend a lot of time on incident analysis in order to better understand future incidents.	123	2,00	5,00	3,6622	,48951
19.7 In our team we spend a lot of time on technical problem analysis to better understand future problems.	123	3,00	5,00	3,8627	,43870
20.1 In our team we listen carefully to each other; it is exceptional that an opinion is not listened to.	123	3,00	5,00	4,1378	,36691
20.2 In our team we trust each other.	123	3,00	5,00	4,1927	,29307
20.3 When handling an urgent incident (priority 0) we consult other team members.	118	2,00	4,60	3,6182	,49822
20.4 I know which assignments are crucial.	123	3,67	5,00	4,1896	,27327
20.5 There is consensus amongst the members of our team on HOW things could go wrong with crucial systems.	122	3,00	5,00	4,1264	,31816
20.6 There is consensus amongst the members of our team on HOW things could go wrong with crucial systems.	122	2,00	5,00	3,9160	,41189
20.7 Because of pressure (time-pressure or other) our team often deviates from procedure.	123	1,00	4,00	2,0707	,42193
22.1 I feel a lot of pressure to save on costs and time.	123	2,00	4,00	2,9537	,53973
22.2 I have a lot of freedom when handling incidents.	124	2,29	5,00	3,6210	,63641
22.3 I feel I receive challenging assingments.	124	3,00	5,00	3,6371	,44279
22.4 I have sufficient training and experience to handle incidents.	124	3,00	5,00	3,8746	,39664
22.5 When necessary, superiors let subordinates with more technical expertise make decisions.	124	2,71	4,50	3,6363	,42433
23.1 [COMPANY] is exposed to many dangers/threats.	124	2,00	4,00	3,0242	,52427
23.2 My management mobilizes supplementary people whenever the workload of our teams becomes excessive.	124	1,86	4,50	2,8704	,59612
23.3 In [COMPANY] it is easy to ask for help.	124	2,00	4,50	3,5645	,40709

23.4 I feel free to speak to superiors about difficulties in my work situation.	124	3,00	5,00	4,0806	,36986
24.1 I am encouraged to ask questions.	124	2,80	5,00	3,6452	,40698
24.2 I am familiar with processes that are strictly speaking outside the scope of my job.	124	2,00	4,50	3,3656	,39063
24.3 I am expected to do my job in a certain manner without deviating from procedure.	124	2,00	5,00	3,7581	,46729
Q243INV	124	1,00	4,00	2,2419	,46729
24.4 I often work under high productivity pressure (time, costs).	124	2,80	5,00	3,5645	,39648
Q244INV	124	1,00	3,20	2,4355	,39648
25. When we do not dispose of a particular type of knowledge/information, we know who in our organization can help us.	124	2,60	5,00	3,7177	,41215
26. I feel free to contact people outside of our team about difficulties in my work.	124	3,00	5,00	3,8669	,30166
27. The interaction between the different steps in the maintenance & repair process runs smoothly.	123	2,00	4,33	3,2766	,51447
28. The order in which you perform tasks that are necessary to solve a problem can vary.	124	2,00	5,00	3,6774	,39123
29. The Maintenance & Repair process has built-in buffers/security in case something goes wrong or makes a mistake.	124	2,00	4,00	3,3230	,37852
Q29INV	124	2,00	4,00	2,6770	,37852
30. The systems and processes I am responsible for, have no secrets for me.	124	1,00	5,00	3,0645	,48845
Q30INV	124	1,00	5,00	2,9355	,48845
31. The systems and processes in our work, can lead to unpredictable reactions.	124	1,00	4,00	3,0339	,50741
32. The systems and processes in our work are tightly coupled.	124	3,00	4,67	3,8367	,34980
Q32INV	124	1,33	3,00	2,1633	,34980
33. The information that is needed for my work can come from many different sources.	123	3,50	5,00	4,1450	,31530
Efficiency	124	1,50	5,00	3,2742	,70525
SupRes	124	1,67	4,67	3,4718	,64592
Deviation	124	2,00	5,00	3,7581	,82018

Team Orientation	120	2,67	5,00	4,1889	,46964
Sensitivity to Operations	120	3,00	5,00	4,1542	,43384
Preoccupation with Failure	124	3,00	5,00	4,2931	,41620
Deference to Expertise	124	2,40	5,00	3,8177	,44118
HRT	124	3,00	4,94	4,1003	,33223
Other	120	2,50	5,00	4,0014	,54938
Self	124	2,00	5,00	4,1089	,61671
Scheme	123	1,00	5,00	2,6504	,88228
SeMa	124	2,71	4,43	3,6443	,38365
Threat Flexibility	124	3,17	4,50	3,6156	,26381
Efficiency	124	2,50	4,50	3,2742	,38662
Pressure	124	2,33	4,33	3,2124	,36325
SupRes	124	2,76	4,67	3,4718	,35956
Deviation	124	2,00	5,00	3,7581	,46729
TO	123	3,50	5,00	4,1912	,27868
SO	123	3,50	5,00	4,1497	,25005
Preoccupation with Failure	124	3,60	4,90	4,2931	,24626
DE	124	3,20	4,60	3,8177	,24413
HRT	124	3,60	4,74	4,1003	,18064
Other	123	3,33	4,50	4,0037	,30691
Self	124	3,00	4,50	4,1089	,28803
Scheme	124	1,00	4,50	2,6391	,53912
SeMa	124	3,24	4,29	3,6443	,20749
Valid N (listwise)	30				

Appendix F. Descriptive Team Statistics (Bank Case)

	N	*Min.*	*Max.*	*Mean*	*Std. Deviation*
6. What team are you a member of? In case you are a member of more than one team, indicate that team where you feel most part of.	37	2	65	33,95	19,449
1. Are you an internal or external employee?	37	1,00	2,00	1,2366	,21524
2. What is your gender?	37	1,00	2,00	1,2216	,23919
4. At what physical location do you work?	37	1,00	9,00	4,1881	2,43490
5. How many years of experience with incident handling do you have?	37	3,00	23,33	7,4828	4,09775
Team Size	37	4,00	36,00	11,8378	6,51287
7. What department are you a member of?	37	2,00	21,00	8,9221	5,61222
8. How much of your time (%) do you spend in handling incidents?	37	4,33	78,75	20,2337	14,19904
Q9	37	56,11	100,00	85,4289	12,27276
10. How much (%) do you register allmost immediately the necessary data in Peregrine?	37	37,00	92,25	69,2769	15,17100
11.1 face-to-face communication	37	6,67	25,00	15,6305	5,33051
11.2 telephone/cell phone	37	7,50	60,00	30,6649	9,71278
11.3 e-mail	37	5,27	60,00	21,3738	9,44950
11.4 Peregrine	37	12,50	73,75	37,7853	13,57361
11.5 Other means of communication	24	1,00	11,67	6,0645	3,15934
Ratio non dedicated vs dedicated	37	,42	33,81	5,5101	6,41696
Ratio voice vs non voice	37	,22	3,57	1,2327	,84678
Ratio face vs distance	37	,06	,65	,1758	,12507
13.1 I feel emotionally involved when handling incidents. The work does not let go.	37	2,00	4,25	3,4964	,46545
13.2 I consider the adequate handling of incidents as a matter of honour.	37	3,17	5,00	4,1941	,36927
13.3 When handling incidents I call similar prior incidents to mind.	37	3,67	4,83	4,2645	,24039
13.4 When making decisions/taking action I take into account the possible reaction of my colleagues.	37	3,00	4,40	3,7230	,38674

13.5 When problems arise, I know where/how I can reach a decision-maker.	37	3,17	4,67	4,1719	,32094
13.6 I dispose of a number of informal contacts that I use to deal with problems.	37	3,33	4,67	3,9878	,32124
13.7 When handling an incident I deal with it incrementally. I adjust my actions.	37	3,20	4,67	4,0468	,28193
14.1 When something exceptional happens, I know who has the expertise to respond.	37	3,50	4,67	4,0270	,27998
14.2 I sometimes rely on improvisation to find a solution.	37	2,00	4,40	3,3457	,49504
14.3 To perform the job, I sometimes defer from procedure.	37	2,33	4,20	3,4881	,39416
14.4 When handling an incident I take into account the consequences for the organization as a whole.	37	3,75	4,67	4,2989	,21463
14.5 When I handle an incident, I sometimes rely on information that is (or does not need to be) 100% certain.	37	2,17	3,67	2,8972	,42289
IntuitiefipvRationeel	37	1,50	2,86	2,1739	,27914
15.1 I consider near-misses as an indication of potential danger.	37	3,25	4,67	3,9358	,31257
15.2 I consider near-misses and mistakes as information on the performance of our system.	37	3,33	4,33	3,8830	,23491
15.3 I tend to report mistakes that could have important consequences, even when no-one has noticed them.	37	3,80	4,83	4,3753	,25237
15.4 When the unexpected happens, I investigate why things did not go as expected.	37	3,80	4,67	4,2323	,20060
17.1 When handling a severe incident (priority 1 or 2) it is easy to get hold of all necessary information.	37	2,17	4,00	3,3129	,41247
17.2 When handling an incident of priority 1 or 2 it is easy to get access to supplementary resources.	37	3,17	4,50	3,8818	,34482
19.1 When the unexpected happens, we report in our team what has happend prior to the incident.	37	2,75	4,50	3,8951	,36538
19.2 In our team we learn from our mistakes.	37	3,67	4,75	4,1797	,25747
19.3 I feel good in our team.	37	3,67	4,83	4,2699	,31904
19.4 As a team we feel ownership for the incident untill it is solved.	37	3,50	4,67	4,2044	,30013
19.5 In our team we take into account each other’s opinion regarding the handling of incidents.	37	3,63	4,75	4,1510	,27366
19.6 In our team we spend a lot of time on incident analysis in order to better understand future incidents.	37	2,40	4,67	3,5677	,46039
20.1 In our team we listen carefully to each other; it is	37	3,20	4,80	4,0793	,31276

exceptional that an opinion is not listened to.					
20.2 In our team we trust each other.	37	3,29	4,80	4,1293	,32385
20.3 When handling a severe incident (priority 1 or 2) we consult other team members.	37	3,50	4,67	4,2525	,32972
20.4 There is consensus amongst the members of our team on WHAT should not go wrong with crucial systems.	37	3,33	4,40	3,9638	,24273
20.5 There is consensus amongst the members of our team on HOW crucial systems can go wrong.	37	3,29	4,40	3,8026	,26170
20.6 Because of pressure (time-pressure or other) our team often deviates from procedure.	37	2,00	3,50	2,7960	,41121
22.1 I feel a lot of pressure to save on costs and time.	37	2,83	4,67	3,6262	,45986
22.2 I have a lot of freedom when handling incidents.	37	2,50	5,00	3,5865	,44847
22.3 I feel I receive challenging assingments.	37	2,67	4,00	3,4934	,37134
22.4 I have sufficient training and experience to handle incidents.	37	3,22	5,00	3,8699	,33938
22.5 When necessary, superiors let subordinates with more technical expertise make decisions.	37	2,67	4,67	3,8173	,35448
23.1 [COMPANY]-ICT is exposed to many dangers/threats.	37	2,33	3,50	3,1336	,26093
23.2 My management mobilizes supplementary people whenever the workload of our teams becomes excessive.	37	2,25	4,25	3,2422	,46042
23.3 In [COMPANY]-ICT it is easy to ask for help.	37	3,18	4,33	3,6940	,27266
23.4 I feel free to speak to superiors about difficulties in my work situation.	37	3,25	4,67	3,9199	,29545
24.1 I am encouraged to ask questions.	37	2,83	4,50	3,7073	,37941
24.2 I am familiar with processes (business or IT) that are strictly speaking outside the scope of my job.	37	2,50	4,40	3,2848	,38183
Deviation	37	2,00	3,17	2,6488	,29698
24.4 I often work under high productivity pressure (time, costs).	37	3,00	4,42	3,5693	,37156
NU12 deadline alert	37	1,00	357,00	59,8378	80,03628
NU12 closed	37	2,00	2248,00	194,6757	391,97754
PU12 resolved on time	37	,00	87,32	55,6210	23,46889
NU3 deadline alert	37	,00	96,00	29,0270	25,83009
NU3 closed	37	11,00	69749,00	2942,3514	11394,79985

PU3 resolved on time	37	41,89	100,00	93,6303	11,53535
NUA deadline alert	37	1,00	417,00	88,8649	98,47593
NUA closed	37	14,00	69785,00	3137,0270	11372,27344
PUA resolved on time	37	32,73	99,91	87,1434	15,29910
Mean NU12 per employee	37	,22	132,24	14,7402	24,19485
Mean NU3 per employee	37	2,75	3321,38	208,0978	558,94713
Mean NUA per employee	37	3,50	3323,10	222,8380	555,99184
Team Orientation	37	3,55	4,60	4,1633	,22298
Preoccupation with Failure	37	3,75	4,47	4,1451	,14693
Deference to Expertise	37	3,36	4,20	3,7556	,19547
Sensitivity to Operations	37	3,50	4,40	3,8832	,22418
HRT	37	3,77	4,26	3,9912	,11385
SenseMaking	37	3,32	4,05	3,7293	,17447
Other	37	3,19	4,25	3,8414	,27070
Self	37	3,00	4,50	3,8453	,30591
Scheme	37	2,78	4,13	3,5025	,27394
Threat Flexibility	37	3,29	4,20	3,6941	,21486
Efficiency	37	3,00	4,18	3,5978	,33402
Logics of Action	37	3,25	4,44	3,8147	,23830
Deviation	37	2,50	3,60	3,0685	,24605
Team Size	37	4	36	11,84	6,513
Valid N (listwise)	24				

Appendix G. Descriptive Team Statistics (NPP Case)

	N	*Min.*	*Max.*	*Mean*	*Std. Deviation*
Deference to Expertise (DE)	24	3,47	4,60	3,8375	,25530
Deviation	24	3,00	4,33	3,7222	,38616
Efficiency (Eff)	24	2,60	3,86	3,2112	,33684
High Reliability Theory (HRT)	24	3,60	4,74	4,1210	,21450
Other	24	3,44	4,50	4,0374	,33292
Preoccupations with Failure (PF)	24	3,60	4,90	4,2879	,28058
Pressure	24	2,60	3,76	3,1743	,30715
Scheme	24	1,25	3,50	2,5824	,52405
Self	24	3,50	4,50	4,1237	,28036
SenseMaking (SeMa)	24	3,24	4,07	3,6543	,22483
Sensitivity to Operations (SO)	24	3,67	5,00	4,1704	,32131
Supplementary Resources (SupRes)	24	2,76	4,00	3,4760	,31976
Team Orientation (TO)	24	3,75	5,00	4,2506	,32341
Threat Flexibility (TF)	24	3,22	4,50	3,6671	,30368
Number of team members (TM)	24	2	11	4,46	2,467
Number of urgent notifications per employee (N0pe)	24	,20	292,45	46,8322	62,14910
Number of non-urgent notifications per employee (N123pe)	24	,33	436,91	53,1870	90,61430
Number of notifications per employee (NApe)	24	,53	729,36	100,0191	151,92554
Team Participation (TP)	24	,11	1,00	,3493	,19698
1. Ben je [company] personeel of contractor?	24	1,00	1,50	1,0313	,11211
10. In how many of the cases (%) do you timely register the necessary data in SAP?	24	5,00	100,00	65,5115	21,14723
11.1 face-to-face communication	24	15,00	82,50	42,5240	21,35135
11.2 telephone/cell phone	24	3,37	80,00	30,1366	15,15244
11.3 e-mail	24	,00	80,00	29,9078	16,75122

11.4 SAP	24	10,00	63,50	39,0600	13,18074
11.5 Other means of communication	24	,00	52,50	4,8007	11,14991
13.7 When handling an incident I deal with it incrementally. I adjust my actions.	24	3,00	4,50	3,9498	,33317
2. What is your gender?	24	1,00	1,50	1,0396	,11701
3.1. Are you a manager?	24	1,00	2,00	1,3948	,33351
3.2. What personnel category do you belong to?	24	1,00	2,25	1,5871	,33162
4. What is your physical work location?	24	1,00	6,00	2,4146	1,37378
5. How many years of experience do you have regarding the Maintenance & Repair process?	24	,53	23,29	9,2827	5,36222
7.1. How much (%) do you use SAP history for the work preparation?	24	7,50	90,00	36,0900	20,69900
7.2. From how many different people do you get input (conversation, telephone, e-mail, notifications)?	23	12,50	733,33	211,1306	203,62842
Q72LIKERT	23	1,50	5,00	3,0391	,99496
8. How many of the cases (%) do you notice a procedure needs to be adjusted?	24	2,00	37,50	14,7288	8,95689
9. In how many of the cases (%) do you take action to change the procedure?	24	5,00	100,00	76,8371	23,14973
Ratio face vs distance	24	,10	1,76	,5642	,42393
Ratio nondedicated vs dedicated	24	,00	24,00	5,4369	5,06875
Ratio voice vs nonvoice	24	,00	4,67	1,4851	1,07004
Team Size	24	4	70	18,04	18,700

Appendix H. Data Reduction (Bank Case)

Control variables

An overview of all variables is shown in Appendix D (Bank Case) and Appendix E (NPP Case). It was the basis for our further analysis. We have used factor analysis to reduce various sets of items into a smaller number of compound factors. All factors are extracted by Principal Component Analysis with Varimax rotation with Kaiser Normalization. First, we isolated the moderator items () from the items relating to theory and we performed a factor analysis on the first set. We only performed such an analysis if the necessary conditions are met: KMO measure higher than 0.50 and a significant value of the Bartlett test (Poelmans, 2002, p. 135) (Table 0.10). The factors emerging from our analysis meet the exigency that they should explain for 60% of total Variance (Table 0.11). Our approach is in line with Koch's (1993) modus operandus and has lead to the results shown in Table 6.1 and Table 6.2, for the Bank Case and the NPP Case respectively.

	Mean	*Std. Deviation*	*Analysis N*	*Missing N*
24.1 I am encouraged to ask questions.	3,62	0,699	317	3
22.3 I feel I receive challenging assingments.	3,46	0,777	312	8
23.3 In [COMPANY]-ICT it is easy to ask for help.	3,63	0,667	314	6
17.2 When handling an incident of priority 1 or 2 it is easy to get access to supplementary resources.	3,79	0,742	289	31
24.4 I often work under high productivity pressure (time, costs).	3,57	0,829	314	6
22.1 I feel a lot of pressure to save on costs and time.	3,58	0,910	313	7
13.6 I dispose of a number of informal contacts that I use to deal with problems.	4,03	0,710	310	10
22.4 I have sufficient training and experience to handle incidents.	3,82	0,792	308	12
22.2 I have a lot of freedom when handling incidents.	3,55	0,851	307	13
24.3 I am expected to do my job in a certain manner without deviating from procedure.	3,34	0,792	315	5
14.3 To perform the job, I sometimes defer from procedure.	3,54	0,847	309	11

Table 0.9 - Items relating to Control Variables (Bank)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,618
Bartlett's Test of Sphericity	Approx. Chi-Square	359,479
	df	55
	Sig.	,000

Table 0.10 - KMO and Bartlett's Test for Control Variables (Bank)

Com-ponent	*Total*	*% Var.*	*Cum.%*	*Total*	*% of Var.*	*Cum.%*	*Total*	*% Var.*	*Cum.%*
1	2,174	19,760	19,760	2,174	19,760	19,760	1,869	16,988	16,988
2	1,704	15,492	35,252	1,704	15,492	35,252	1,706	15,513	32,501
3	1,350	12,272	47,524	1,350	12,272	47,524	1,492	13,560	46,061
4	1,111	10,095	57,619	1,111	10,095	57,619	1,271	11,558	57,619
5	,890	8,087	65,707						
6	,819	7,446	73,153						
7	,702	6,378	79,531						
8	,627	5,701	85,232						
9	,602	5,468	90,700						
10	,580	5,276	95,976						
11	,443	4,024	100,000						

Table 0.11 - Total Variance Explained by the Factors for the Control Variables (Bank)

	Component			
	1	2	3	4
24.1 I am encouraged to ask questions.	0,674912	-0,07482	-0,03762	0,128155
22.3 I feel I receive challenging assingments.	0,658099	-0,06776	0,12968	0,150919
17.2 When handling an incident of priority 1 or 2 it is easy to get access to supplementary resources.	0,629954	0,279555	0,004025	-0,20017
23.3 In [COMPANY]-ICT it is easy to ask for help.	0,610508	-0,17318	0,130691	-0,04616
24.4 I often work under high productivity pressure (time, costs).	-0,00729	0,824612	0,12017	-0,16194

22.1 I feel a lot of pressure to save on costs and time.	-0,07863	0,777188	-0,10134	0,123354
13.6 I dispose of a number of informal contacts that I use to deal with problems.	-0,14782	0,167159	0,724447	0,138339
22.4 I have sufficient training and experience to handle incidents.	0,274569	0,019724	0,702002	-0,26601
22.2 I have a lot of freedom when handling incidents.	0,220746	-0,24842	0,599949	0,240725
24.3 I am expected to do my job in a certain manner without deviating from procedure.	-0,21081	0,279237	0,057654	-0,71778
14.3 To perform the job, I sometimes defer from procedure.	-0,11767	0,368895	0,225107	0,696784

Table 0.12 - Rotated Component Matrix for Control Variables

Threat Flexibility	24.1 I am encouraged to ask questions. 22.3 I feel I receive challenging assingments. 23.3 In [COMPANY]-ICT it is easy to ask for help. 23.2 My management mobilizes supplementary people whenever the workload of our teams becomes excessive. 17.2 When handling an incident of priority 1 or 2 it is easy to get access to supplementary resources.
Efficiency	24.4 I often work under high productivity pressure (time, costs). 22.1 I feel a lot of pressure to save on costs and time.
Peregrine	10. How much (%) do you register allmost immediately the necessary data in Peregrine? 9. How much (%) do you rely on Peregrine for the registration/coordination /escalation/closing of an incident?
Logics of Action	13.6 I dispose of a number of informal contacts that I use to deal with problems. 22.4 I have sufficient training and experience to handle incidents. 22.2 I have a lot of freedom when handling incidents.
Deviation	24.3INV

14.3 To perform the job, I sometimes defer from procedure.
IntuitiefipvRationeel
20.6 Because of pressure (time-pressure or other) our team often deviates from procedure.

Table 0.13 - Labeling of the factors based on moderator variables

HRT and SeMa

Next, we chose to split the items in two sets: a set of items relating to theory (HRT and SeMa), and another set relating to the moderator variables. By doing so we obtained the result shown in Table 0.14.

Some constructs could be labeled according to theoretical constructs and sub-constructs. For the factors relating to HRT, we refer to Weick et al. (1999). For the factors relating to Scheme and making sense of uncertainty, we specifically refer to our relabeling of SenseMaking in Chapter 4 (Conceptual Model). Other constructs could not be labeled according to theoretical constructs and sub-constructs. For these factors we have chosen a new, best-fitting, label (e.g. Team Orientation). The factors in bold (Table 0.18) have a sufficiently high internal consistency (Cronbach's alpha ≥.60) to allow for aggregating them in a compounded indicator.

	Mean	*Std. Deviation*	*Analysis N*	*Missing N*
13.5 When problems arise, I know where/how I can reach a decision-maker.	4,13	,677	314	6
14.1 When something exceptional happens, I know who has the expertise to respond.	3,98	,655	313	7
14.4 When handling an incident I take into account the consequences for the organization as a whole.	4,29	,567	311	9
15.1 I consider near-misses as an indication of potential danger.	3,92	,666	296	24
15.2 I consider near-misses and mistakes as information on the performance of our system.	3,88	,648	297	23
15.3 I tend to report mistakes that could have important consequences, even when no-one has noticed them.	4,38	,577	313	7
15.4 When the unexpected happens, I investigate why things did not go as expected.	4,24	,599	310	10
17.1 When handling a severe incident (priority 1 or 2) it is easy to get hold of all necessary information.	3,26	,853	290	30
19.4 As a team we feel ownership for the	4,14	,653	313	7

incident untill it is solved.				
19.5 In our team we take into account each other's opinion regarding the handling of incidents.	4,12	,587	313	7
20.1 In our team we listen carefully to each other; it is exceptional that an opinion is not listened to.	4,05	,657	312	8
20.2 In our team we trust each other.	4,11	,631	313	7
20.3 When handling a severe incident (priority 1 or 2) we consult other team members.	4,20	,676	296	24
20.4 There is consensus amongst the members of our team on WHAT should not go wrong with crucial systems.	3,96	,640	300	20
20.5 There is consensus amongst the members of our team on HOW things could go wrong with crucial systems.	3,76	,638	297	23
22.5 When necessary, superiors let subordinates with more technical expertise make decisions.	3,79	,750	300	20
23.4 I feel free to speak to superiors about difficulties in my work situation.	3,85	,732	313	7
24.2 I am familiar with processes (business or IT) that are strictly speaking outside the scope of my job.	3,31	,823	312	8

Table 0.14 - Descriptive Statistics for items relating to HRT

The KMO analysis (Table 0.15) results in a value of 0.795 which can be considered meritorious (Poelmans, 2002) and the Bartlett's Test of Sphericity is significant ($p \leq 0.001$).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,795
Bartlett's Test of Sphericity	Approx. Chi-Square	1190,447
	df	153
	Sig.	,000

Table 0.15 - KMO and Bartlett's Test for HRT Factor Analysis

Subsequently a factor analysis was run on these items, resulting in the Rotation Component Matrix shown in Table 0.17 from which four factors can be derived, cumulatively explaining 50.43% of total variance (Table 0.16). From Table 0.17 can be derived the items underlying the factors relating to the HRT constructs. As the factor composition matched the factor composition of the Bank Case, they got labeled accordingly (Table 0.18).

Component	*Initial Eigenvalues*			*Extraction Sums of Squared Loadings*			*Rotation Sums of Squared Loadings*		
	Total	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*
1	4,338	24,098	24,098	4,338	24,098	24,098	2,944	16,356	16,356
2	2,012	11,176	35,274	2,012	11,176	35,274	2,342	13,009	29,366
3	1,459	8,105	43,379	1,459	8,105	43,379	2,016	11,201	40,566
4	1,269	7,048	50,427	1,269	7,048	50,427	1,775	9,860	50,427
5	,977	5,427	55,854						
6	,934	5,189	61,043						
7	,859	4,772	65,815						
8	,832	4,623	70,438						
9	,771	4,286	74,723						
10	,739	4,104	78,827						
11	,664	3,690	82,517						
12	,607	3,374	85,890						
13	,573	3,184	89,074						
14	,536	2,978	92,052						
15	,437	2,426	94,477						
16	,396	2,201	96,678						
17	,323	1,795	98,474						
18	,275	1,526	100,000						

Table 0.16 - Total Variance Explained by the HRT Factors (Bank)

	Component			
	1	2	3	4
20.2 In our team we trust each other.	0,779539	0,037776	0,101271	0,147273
20.1 In our team we listen carefully to each other; it is exceptional that an opinion is not listened to.	0,779074	0,006255	0,076774	0,193751
19.5 In our team we take into account each other's opinion regarding the handling of incidents.	0,728231	0,133892	0,155673	0,126674
19.4 As a team we feel ownership for the incident untill it is solved.	0,584455	0,292655	0,055097	0,009185
20.3 When handling a severe incident (priority 1 or 2) we consult other team members.	0,486741	0,039816	0,173282	0,31757
15.1 I consider near-misses as an indication of potential danger.	-0,02712	0,686307	0,03997	0,091803
15.3 I tend to report mistakes that could have important consequences, even when no-one has noticed them.	0,291055	0,669452	0,028237	-0,2635
14.4 When handling an incident I take into account the consequences for the organization as a whole.	0,107064	0,638492	0,019427	0,134006
15.2 I consider near-misses and mistakes as information on the performance of our system.	-0,10705	0,631128	0,002229	0,447503
15.4 When the unexpected happens, I investigate why things did not go as expected.	0,229484	0,615763	0,138503	-0,10685
13.5 When problems arise, I know where/how I can reach a decision-maker.	0,090566	0,059052	0,695075	0,0867
14.1 When something exceptional happens, I know who has the expertise to respond.	-0,04398	0,258817	0,690137	-0,04908
22.5 When necessary, superiors let subordinates with more technical expertise make decisions.	0,220019	-0,01888	0,524863	0,040273
17.1 When handling a severe incident (priority 1 or 2) it is easy to get hold of all necessary information.	0,12746	-0,18948	0,503384	0,077087
23.4 I feel free to speak to superiors about difficulties in my work situation.	0,427503	0,054195	0,446155	0,007562
24.2 I am familiar with processes (business or IT) that are strictly speaking outside the scope of my job.	0,018834	0,117848	0,423331	0,188404

20.5 There is consensus amongst the members of our team on HOW things could go wrong with crucial systems.	0,3024	-0,00321	0,200798	0,788595
20.4 There is consensus amongst the members of our team on WHAT should not go wrong with crucial systems.	0,332119	0,084327	0,117706	0,784991

Table 0.17 - Rotation Matrix for HRT constructs

Team Orientation	20.1 In our team we listen carefully to each other; it is exceptional that an opinion is not listened to. 20.2 In our team we trust each other. 19.5 In our team we take into account each other's opinion regarding the handling of incidents. 19.4 As a team we feel ownership for the incident untill it is solved. 20.3 When handling a severe incident (priority 1 or 2) we consult other team members. 23.4 I feel free to speak to superiors about difficulties in my work situation.
Preoccupation with Failure	15.1 I consider near-misses as an indication of potential danger. 15.3 I tend to report mistakes that could have important consequences, even when no-one has noticed them. 14.4 When handling an incident I take into account the consequences for the organization as a whole. 15.4 When the unexpected happens, I investigate why things did not go as expected. 15.2 I handle near-misses and mistakes as information on the reliability of our system.
Deference to Expertise	14.1 When something exceptional happens, I know who has the expertise to respond. 13.5 When problems arise, I know where/how I can reach a decision-maker. 24.2 I am familiar with processes (business or IT) that are strictly speaking outside the scope of my job. 22.5 When necessary, superiors let subordinates with more technical expertise make decisions. 17.1 When handling a severe incident (priority 1 or 2) it is easy to get hold of all necessary information.

Sensitivity to Operations	20.5 There is consensus amongst the members of our team on HOW crucial systems can go wrong. 20.4 There is consensus amongst the members of our team on WHAT should not go wrong with crucial systems.
Making sense of Other	19.1 When the unexpected happens, we report in our team what has happend prior to the incident. 19.2 In our team we learn from our mistakes. 19.6 In our team we spend a lot of time on incident analysis in order to better understand future incidents. 13.4 When making decisions/taking action I take into account the possible reaction of my colleagues.
Making sense of Self	13.1 I feel emotionally involved when handling incidents. The work does not let go. 13.2 I consider the adequate handling of incidents as a matter of honour..
Scheme	14.5 When I handle an incident, I sometimes rely on information that is (or does not need to be) 100% certain. 14.2 I sometimes rely on improvisation to find a solution. 13.3 When handling incidents I call similar prior incidents to mind.

Table 0.18 - Labeling of HRT constructs based on the research data

Next, the procedure was repeated for the items relating to SenseMaking (Table 0.19). These items were factor analyzed.

	Mean	*Std. Deviation*	*Analysis N*	*Missing N*
19.2 In our team we learn from our mistakes.	4,17	,577	314	6
19.6 In our team we spend a lot of time on incident analysis in order to better understand future incidents.	3,51	,896	309	11
19.1 When the unexpected happens, we report in our team what has happend prior to the incident.	3,85	,773	311	9
13.1 I feel emotionally involved when handling incidents. The work does not let go.	3,46	1,043	306	14
13.3 When handling incidents I call similar prior incidents to mind.	4,27	,639	312	8
13.2 I consider the adequate handling of incidents as a matter of honour..	4,13	,764	309	11
14.2 I sometimes rely on improvisation to find a solution.	3,39	,884	311	9
14.5 When I handle an incident, I sometimes rely on information that is (or does not need to be) 100% certain.	2,83	,965	309	11
13.4 When making decisions/taking action I take into account the possible reaction of my colleagues.	3,79	,896	307	13

Table 0.19 - Descriptive Statistics for SenseMaking related items

The KMO analysis (Table 0.20) results in a value of 0.651 which can be considered mediocre and the Bartlett's Test of Sphericity is significant ($p \leq 0.001$) (Poelmans, 2002). The three factors explain 55.84% of total variance of the eigenvalues (Table 0.21).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,651
Bartlett's Test of Sphericity	Approx. Chi-Square	359,671
	df	36
	Sig.	,000

Table 0.20 - KMO and Bartlett's Test for SenseMaking Factors (Bank)

Component	*Initial Eigenvalues*			*Extraction Sums of Squared Loadings*			*Rotation Sums of Squared Loadings*		
	Total	*% Var*	*Cum.%*	*Total*	*% of Var*	*Cum. %*	*Total*	*% of Var.*	*Cum.%*
1	2,251	25,008	25,008	2,251	25,008	25,008	2,095	23,277	23,277
2	1,494	16,603	41,611	1,494	16,603	41,611	1,648	18,311	41,588
3	1,281	14,232	55,843	1,281	14,232	55,843	1,283	14,256	55,843
4	,845	9,387	65,230						
5	,827	9,193	74,423						
6	,774	8,596	83,019						
7	,568	6,313	89,332						
8	,564	6,268	95,600						
9	,396	4,400	100,000						

Table 0.21 - Total Variance Explained by the SenseMaking Factors (Bank)

From Table 6.2 can be derived the items underlying the factors relating to the SeMa constructs. As the factor composition matched the onoe of the Bank Case, they got labeled accordingly (Table 6.1).

	Component		
	1	*2*	*3*
19.2 In our team we learn from our mistakes.	0,82791	-0,04916	0,072066
19.1 When the unexpected happens, we report in our team what has happend prior to the incident.	0,825758	-0,06752	0,101278
19.6 In our team we spend a lot of time on incident analysis in order to better understand future incidents.	0,66467	0,198809	-0,17084
13.4 When making decisions/taking action I take into account the possible reaction of my colleagues.	0,489268	0,205248	-0,06493
13.1 I feel emotionally involved when handling incidents. The work does not let go.	0,016869	0,789055	-0,14554
13.2 I consider the adequate handling of incidents as a matter of honour..	0,087022	0,777071	-0,04115
13.3 When handling incidents I call similar prior incidents to mind.	0,150058	0,575723	0,388872
14.2 I sometimes rely on improvisation to find a solution.	0,054505	-0,01671	0,768505
14.5 When I handle an incident, I sometimes rely on information that is (or does not need to be) 100% certain.	-0,11451	-0,03377	0,685168
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 4 iterations.			

Table 0.22 - Rotation Matrix for SenseMaking (Bank)

Appendix I. Data Reduction (NPP Case)

We proceeded by analogy with the Bank Case as follows:

Control Variables

First, we isolated the moderator items from the items relating to theory and we performed a factor analysis on the first set (Table 0.23). We only performed such an analysis if the necessary conditions are met: KMO measure higher than 0.5 and a significant value of the Bartlett test (Table 0.24) (Poelmans, 2002, p. 135).

	Mean	*Std. Deviation*	*Analysis N*	*Missing N*
24.1 I am encouraged to ask questions.	3,72	,832	128	0
22.3 I feel I receive challenging assingments.	3,71	,824	128	0
23.3 In [COMPANY] it is easy to ask for help.	3,64	,839	128	0
17.2 When handling an incident of priority 0 it is easy to get access to supplementary resources.	3,89	1,449	128	0
24.4 I often work under high productivity pressure (time, costs).	3,64	,839	128	0
22.1 I feel a lot of pressure to save on costs and time.	3,13	1,143	128	0
13.6 I dispose of a number of informal contacts that I use to deal with problems.	3,66	1,089	128	0
22.4 I have sufficient training and experience to handle incidents.	3,96	,798	128	0
22.2 I have a lot of freedom when handling incidents.	3,70	,985	128	0
24.3 I am expected to do my job in a certain manner without deviating from procedure.	3,83	,897	128	0
14.3 To perform the job, I sometimes defer from procedure.	3,24	1,169	128	0

Table 0.23 - Descriptive Statistics for items related to moderator items (NPP)

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,703
Bartlett's Test of Sphericity	Approx. Chi-Square	366,740
	df	55
	Sig.	,000

Table 0.24 - KMO and Bartlett's Test for Factor Analysis on Control Variable Items (NPP)

The total variance that can be explained by the factors resulting from this rotation is sufficient (66.17%) (Table 0.25).

Component	*Initial Eigenvalues*			*Extraction Sums of Squared Loadings*			*Rotation Sums of Squared Loadings*		
	Total	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*	*Total*	*% of Variance*	*Cumulative %*
1	3,448	31,343	31,343	3,448	31,343	31,343	2,582	23,471	23,471
2	1,715	15,592	46,936	1,715	15,592	46,936	1,852	16,833	40,304
3	1,115	10,137	57,073	1,115	10,137	57,073	1,602	14,564	54,868
4	1,001	9,100	66,174	1,001	9,100	66,174	1,244	11,306	66,174
5	,801	7,279	73,453						
6	,721	6,556	80,009						
7	,617	5,611	85,620						
8	,489	4,445	90,065						
9	,474	4,312	94,377						
10	,371	3,375	97,751						
11	,247	2,249	100,000						

Table 0.25 - Total Variance Explained by Control Factors (NPP)

By doing so we obtained the result shown in Table 0.26.

	Component			
	1	2	3	4
22.3 I feel I receive challenging assingments.	0,793042	0,265743	0,012742	0,005526
22.2 I have a lot of freedom when handling incidents.	0,689263	0,075591	0,312801	-0,43032
24.1 I am encouraged to ask questions.	0,674437	0,107802	0,237991	0,231671
22.4 I have sufficient training and experience to handle incidents.	0,66928	0,042443	0,022402	0,277159
24.4 I often work under high productivity pressure (time, costs).	0,130925	0,802759	0,082538	0,123202
22.1 I feel a lot of pressure to save on costs and time.	-0,04732	0,786163	0,105917	0,329976
14.3 To perform the job, I sometimes defer from procedure.	0,233215	0,679231	-0,11599	-0,21383
17.2 When handling an incident of priority 0 it is easy to get access to supplementary resources.	-0,00235	0,070339	0,90128	0,055043
13.6 I dispose of a number of informal contacts that I use to deal with problems.	0,455056	0,00422	0,589496	-0,15026
23.3 In [COMPANY] it is easy to ask for help.	0,485522	-0,04516	0,503062	0,281174
24.3 I am expected to do my job in a certain manner without deviating from procedure.	0,241771	0,176149	0,05002	0,808389

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization. Rotation converged in 6 iterations.

Table 0.26 - Rotated Component Matrix for Control Variables (NPP Case)

HRT and SeMa

The same procedure was applied to those items relating to HRT (Table 0.27).

	Mean	*Std. Deviation*	*Analysis N*	*Missing N*
13.5 When problems arise, I know where/how I can reach a decision-maker.	4,20	,836	128	0
14.1 When something exceptional happens, I know who has the expertise to respond.	3,97	,822	128	0
14.4 When handling an incident I take into account the consequences for the organization as a whole.	4,19	,696	128	0
15.1 I consider near-misses as an indication of potential danger.	4,38	,711	128	0
15.2 I handle near-misses and mistakes as information on the reliability of our system.	4,31	,740	128	0
15.3 I tend to report mistakes that could have important consequences, even when no-one has noticed them.	4,54	,614	128	0
15.4 When the unexpected happens, I investigate why things did not go as expected.	4,41	,634	128	0
17.1 When handling a severe incident (priority 0) it is easy to get hold of all necessary information.	3,82	1,405	127	1
19.4 As a team we feel ownership for the incident untill it is solved.	4,34	,788	128	0
19.5 In our team we take into account each other's opinion regarding the handling of incidents.	4,35	,705	128	0

20.1 In our team we listen carefully to each other; it is exceptional that an opinion is not listened to.	4,27	,726	128	0
20.2 In our team we trust each other.	4,32	,742	128	0
20.3 When handling an urgent incident (priority 0) we consult other team members.	4,18	1,213	128	0
20.4 I know which assignments are crucial.	4,32	,663	128	0
20.5 There is consensus amongst the members of our team on HOW things could go wrong with crucial systems..	4,32	,752	128	0
22.5 When necessary, superiors let subordinates with more technical expertise make decisions.	3,76	,929	128	0
23.4 I feel free to speak to superiors about difficulties in my work situation.	4,14	,718	128	0
24.2 I am familiar with processes that are strictly speaking outside the scope of my job.	3,47	,869	128	0

Table 0.27 - Items related to HRT

The KMO analysis (Table 0.28) results in a value of 0.887 which can be considered meritorious (Poelmans, 2002) and the Bartlett's Test of Sphericity is significant ($p \leq 0.001$).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,887
Bartlett's Test of Sphericity	Approx. Chi-Square	965,206
	df	153
	Sig.	,000

Table 0.28 - KMO and Bartlett's Test for Factor Analysis on HRT items

Subsequently a factor analysis was run on these items, resulting in the Rotation Component Matrix shown in Table 0.30 from which four factors can be derived, cumulatively explaining 61.32% of total variance (Table 0.29). From Table 0.30 can be derived the items underlying the factors relating to the HRT constructs. As the factor composition matched the factor composition of the Bank Case, they got labeled accordingly.

Compo-nent	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cum. %	Total	% of Variance	Cum. %	Total	% of Variance	Cum. %
1	6,762	37,567	37,567	6,762	37,567	37,567	3,907	21,706	21,706
2	1,953	10,851	48,418	1,953	10,851	48,418	3,238	17,990	39,696
3	1,286	7,146	55,563	1,286	7,146	55,563	2,302	12,787	52,483
4	1,037	5,759	61,322	1,037	5,759	61,322	1,591	8,839	61,322
5	,904	5,021	66,343						
6	,853	4,737	71,080						
7	,715	3,974	75,054						
8	,633	3,518	78,572						
9	,593	3,293	81,866						
10	,517	2,873	84,739						
11	,441	2,449	87,188						
12	,402	2,235	89,424						
13	,387	2,148	91,572						
14	,357	1,981	93,553						
15	,351	1,948	95,500						
16	,307	1,708	97,208						
17	,296	1,645	98,853						
18	,206	1,147	100,000						

Table 0.29 - Total Variance Explained HRT constructs (NPP Case)

	Component			
	1	*2*	*3*	*4*
19.4 As a team we feel ownership for the incident untill it is solved.	0,805917	0,225291	0,17263	-0,06453
19.5 In our team we take into account each other's opinion regarding the handling of incidents.	0,798533	0,072209	0,309148	0,030481
20.2 In our team we trust each other.	0,769187	0,223861	0,018252	0,169564
20.1 In our team we listen carefully to each other; it is exceptional that an opinion is not listened to.	0,732879	0,119266	0,21503	0,245246
20.4 I know which assignments are crucial.	0,686456	0,208878	0,35489	0,049751
20.5 There is consensus amongst the members of our team on HOW things could go wrong with crucial systems.	0,663605	0,240695	0,023317	0,327856
15.1 I consider near-misses as an indication of potential danger.	0,211704	0,726828	-0,00383	0,248599
14.4 When handling an incident I take into account the consequences for the organization as a whole.	0,26487	0,710737	0,100608	0,000151
15.2 I handle near-misses and mistakes as information on the reliability of our system.	0,08264	0,701886	0,281949	0,114067
15.3 I tend to report mistakes that could have important consequences, even when no-one has noticed them.	0,061786	0,69845	0,167185	0,044508
15.4 When the unexpected happens, I investigate why things did not go as expected.	0,25702	0,658074	0,279043	-0,04206
13.5 When problems arise, I know where/how I can reach a decision-maker.	0,236786	0,497769	0,472131	-0,23803
22.5 When necessary, superiors let subordinates with more technical expertise make decisions.	0,148353	0,15957	0,628949	0,171374

23.4 I feel free to speak to superiors about difficulties in my work situation.	0,391778	0,152033	0,6214	0,097085
24.2 I am familiar with processes that are strictly speaking outside the scope of my job.	0,151695	0,225424	0,613175	0,287231
14.1 When something exceptional happens, I know who has the expertise to respond.	0,124702	0,464247	0,537089	-0,0847
20.3 When handling an urgent incident (priority 0) we consult other team members.	0,339445	0,068124	0,007808	0,762989
17.1 When handling a severe incident (priority 0) it is easy to get hold of all necessary information.	0,051062	0,044247	0,372455	0,735659

Table 0.30 - Rotated Component Matrix for HRT

Next, the procedure was repeated for the items relating to SenseMaking. The items that were supposedly related to SenseMaking were grouped (Table 0.31) and factor analyzed.

	Mean	*Std. Deviation*	*Analysis N*	*Missing N*
19.2 In our team we learn from our mistakes.	4,42	,683	128	0
19.6 In our team we spend a lot of time on incident analysis in order to better understand future incidents.	3,82	1,061	128	0
19.1 When the unexpected happens, we report in our team what has happend prior to the incident.	4,26	,796	128	0
13.1 I feel emotionally involved with my work. The work does not let go.	3,86	,970	128	0
13.3 When handling incidents I call similar prior incidents to mind.	4,20	,787	128	0
13.2 I consider the adequate handling of incidents as a matter of honour.	4,48	,664	128	0
14.2 I sometimes rely on improvisation to find a solution.	3,02	1,292	128	0
14.5 When I handle an incident, I sometimes rely on information that is (or does not need to be) 100% certain.	2,63	1,267	128	0
13.4 When making decisions/taking action I take into account the possible reaction of my colleagues.	3,82	,900	128	0

Table 0.31 - Items Related to SenseMaking

The KMO analysis (Table 0.32) results in a value of 0.752 which can be considered middling and the Bartlett's Test of Sphericity is significant ($p \leq 0.001$) (Poelmans, 2002).

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,752
Bartlett's Test of Sphericity	Aprox. Chi-Square	310,119
	df	36
	Sig.	,000

Table 0.32 - KMO and Bartlett's Test for Factor Analysis on SenseMaking items

From Table 0.33 can be derived the items underlying the factors relating to the SeMa constructs. As the factor composition matched the factor composition of the Bank Case, they got labeled accordingly.

	Component		
	1	*2*	*3*
19.2 In our team we learn from our mistakes.	0,834937	0,162808	0,151281
19.1 When the unexpected happens, we report in our team what has happend prior to the incident.	0,808836	0,163605	0,080555
19.6 In our team we spend a lot of time on incident analysis in order to better understand future incidents.	0,787484	0,1094	0,189624
13.1 I feel emotionally involved with my work. The work does not let go.	0,027415	0,85125	0,023237
13.3 When handling incidents I call similar prior incidents to mind.	0,145967	0,757837	0,225462
13.2 I consider the adequate handling of incidents as a matter of honour.	0,33816	0,663014	-0,17009
13.4 When making decisions/taking action I take into account the possible reaction of my colleagues.	0,16369	0,491224	0,453343
14.2 I sometimes rely on improvisation to find a solution.	0,123443	0,049064	0,864034
14.5 When I handle an incident, I sometimes rely on information that is (or does not need to be) 100% certain.	0,151918	0,027915	0,794955

Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.

Table 0.33 - Rotated Component Matrix for SenseMaking (NPP Case)

Appendix J. Normalized Process Reliability

	N	*Range*	*Minimum*	*Maximum*
Zscore: PU12Year	37	3,72076	-2,36999	1,35077
Zscore: PU3Year	37	5,03739	-4,48520	,55219
Zscore: PUAYear	37	4,39108	-3,55682	,83426
Zscore: PU12Jan	23	3,07840	-1,87752	1,20088
Zscore: PU12Feb	24	3,51438	-1,78266	1,73172
Zscore: PU12Mrt	22	2,81663	-1,34533	1,47131
Zscore: PU12Apr	30	3,24782	-1,83309	1,41473
Zscore: PU12May	29	3,43007	-2,02372	1,40635
Zscore: PU12Jun	30	3,55642	-2,02148	1,53494
Zscore: PU12Jul	29	3,26228	-1,91728	1,34501
Zscore: PU12Aug	29	2,68551	-1,40794	1,27757
Zscore: PU12Sep	31	3,30188	-1,99040	1,31148
Zscore: PU12Oct	31	3,41166	-2,34082	1,07084
Zscore: PU12Nov	32	3,44995	-1,99183	1,45811
Zscore: PU12Dec	28	2,84375	-1,40146	1,44229
Zscore: PU3Jan	27	3,96238	-3,33641	,62597
Zscore: PU3Feb	28	4,62945	-4,06401	,56543
Zscore: PU3Mrt	28	4,24944	-3,73046	,51898
Zscore: PU3Apr	35	4,29728	-3,62560	,67168
Zscore: PU3May	36	4,71747	-4,19621	,52126
Zscore: PU3Jun	35	5,73936	-5,21862	,52074
Zscore: PU3Jul	36	5,47266	-5,05227	,42039
Zscore: PU3Aug	35	4,79958	-4,14012	,65946
Zscore: PU3Sep	37	4,35678	-3,98692	,36986
Zscore: PU3Oct	37	4,61972	-4,12664	,49308
Zscore: PU3Nov	36	5,33167	-4,81682	,51486

Zscore: PU3Dec	36	5,19247	-4,69573	,49673
Zscore: PUAJan	28	5,22378	-4,72210	,50167
Zscore: PUAFeb	28	3,74268	-2,87864	,86405
Zscore: PUAMrt	28	3,55559	-2,73827	,81732
Zscore: PUAApr	35	4,02718	-3,16700	,86019
Zscore: PUAMay	36	4,14928	-3,41943	,72984
Zscore: PUAJun	35	4,81781	-3,88840	,92941
Zscore: PUAJul	36	4,82024	-4,18222	,63802
Zscore: PUAAug	35	4,18379	-3,38935	,79445
Zscore: PUASep	37	4,67746	-4,08140	,59606
Zscore: PUAOct	37	4,40914	-3,73210	,67704
Zscore: PUANov	37	4,90871	-4,13243	,77628
Zscore: PUADec	37	4,42816	-3,74315	,68502
Valid N (listwise)	14			

Table 0.34 - Descriptive Statistics for Normalized Reliability (Bank)

	N	*Range*	*Minimum*	*Maximum*
Zscore: PU0Year	24	4,88034	-4,47932	,40101
Zscore: PU123Year	24	4,64523	-4,10073	,54450
Zscore: PAUYear	24	4,86319	-4,38086	,48232
Zscore: PU0Sep	21	3,08333	-2,58828	,49505
Zscore: PU0Oct	22	4,38224	-3,92281	,45943
Zscore: PU0Nov	21	4,15628	-3,76692	,38936
Zscore: PU0Dec	22	4,01329	-3,37757	,63571
Zscore: PU0Jan	20	4,52649	-4,12816	,39833
Zscore: PU0Feb	23	3,96763	-3,41906	,54857
Zscore: PU0Mrt	23	4,75177	-4,43154	,32023
Zscore: PU0Apr	23	4,13402	-3,68107	,45294
Zscore: PU0May	21	3,51009	-2,85264	,65745
Zscore: PU0Jun	22	4,50153	-4,06979	,43174

Zscore: PU0Jul	20	4,52894	-4,20285	,32608
Zscore: PU0Aug	22	4,13832	-3,81177	,32655
Zscore: PU123Sep	18	3,39753	-2,69348	,70404
Zscore: PU123Oct	20	3,88119	-3,23855	,64264
Zscore: PU123Nov	22	3,68808	-3,09649	,59159
Zscore: PU123Dec	23	3,53178	-2,86935	,66242
Zscore: PU123Jan	22	4,03969	-3,39461	,64509
Zscore: PU123Feb	23	3,97340	-3,44645	,52695
Zscore: PU123Mrt	24	4,25985	-3,74701	,51284
Zscore: PU123Apr	23	4,74845	-4,38152	,36693
Zscore: PU123May	23	4,88451	-4,56209	,32242
Zscore: PU123Jun	23	4,82065	-4,46075	,35990
Zscore: PU123Jul	23	4,74773	-4,31826	,42947
Zscore: PU123Aug	22	4,55869	-4,03981	,51888
Zscore: PUASep	21	3,57641	-3,03245	,54395
Zscore: PUAOct	22	3,88619	-3,24994	,63625
Zscore: PUANov	23	3,71465	-3,04689	,66776
Zscore: PUADec	23	4,62036	-4,12752	,49284
Zscore: PUAJan	22	4,48929	-3,84268	,64661
Zscore: PUAFeb	23	4,65562	-3,99182	,66380
Zscore: PUAMrt	24	4,00746	-3,48936	,51811
Zscore: PUAApr	23	4,29313	-3,77966	,51347
Zscore: PUAMay	23	4,84519	-4,58307	,26212
Zscore: PUAJun	23	4,89441	-4,52366	,37075
Zscore: PUAJul	23	4,86141	-4,53609	,32532
Zscore: PUAAug	23	4,15063	-3,75422	,39642
Valid N (listwise)	17			

Table 0.35 - Descriptive Statistics for Normalized Reliability (NPP)

Appendix K. Incident Management Workflow (Bank Case)

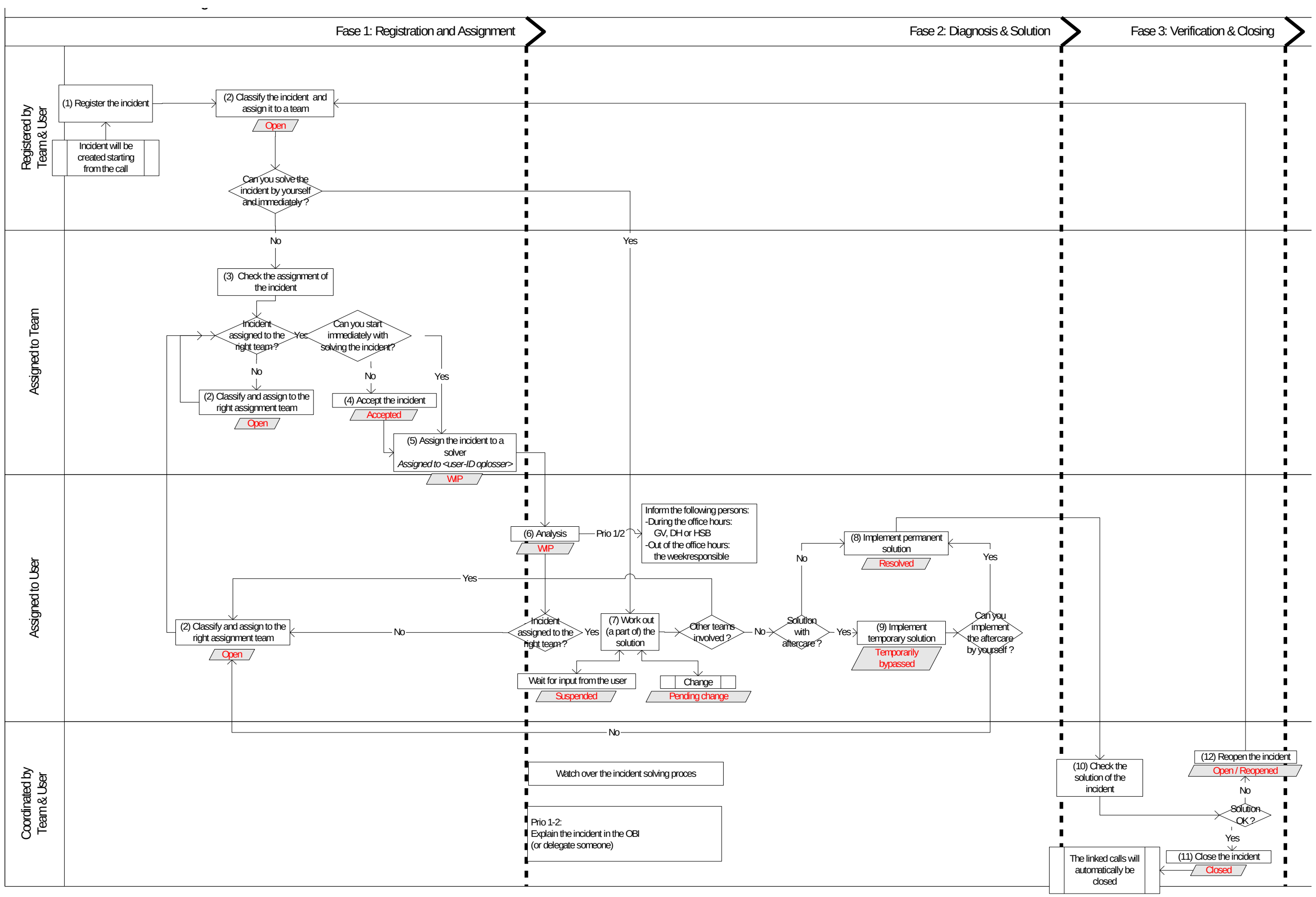

Figure 0.1 - Incident Management Work Flow

Samenvatting (Dutch Summary)

Organizationele betrouwbaarheid is een belangrijk thema binnen elke organisatie. In deze thesis hebben we trachten na te gaan welke contextuele en structurele organisatiedimensies bijdragen tot een hoge betrouwbaarheid van het incident management proces van het IT departement van een financiële instelling en dat van een kerncentrale. We deden dit aan hand van constructen en inzichten die hun oorsprong vinden in onderzoek naar zogenaamde Hoge Betrouwbaarheid Organisaties (HROs) en Sensemaking (SeMa) met de bedoeling een antwoord te vinden op volgende onderzoeksvragen: (1) zijn beide organisaties HROs? en (2) welke factoren dragen bij tot een hoge organizationele betrouwbaarheid? Middels een hermeneutische onderzoeksmethodologie, bouwend op zowel kwalitatieve als kwantitatieve methoden, en na een studie van de belangrijkste literatuur inzake High Reliability Theory (HRT), Normal Accidents Theory, Sensemaking en IS Fit, kwamen we tot een reconceptualisatie van HRT. Het is deze reconceptualizatie die het mogelijk maakt de onderzoeksvragen te beantwoorden zoals hieronder weergegeven.

1. Zijn beide gevalsstudies HROs? Beide organisaties kunnen terecht HRO genoemd worden aangezien de constructen zoals beschreven in onze HRT reconceptualisatie er waargenomen kunnen worden. In het algemeen scoort de kerncentrale (als archetypische HRO) het hoogst op de HRO karakteristieken.

2. Welke factoren dragen bij tot een hoge organizationele betrouwbaarheid? Het antwoord op deze tweede onderzoeksvraag is veel minder eenduidig. In het algemeen stellen we vast dat een hoge score op HRO en SeMa constructen niet noodzakelijkerwijze positief bijdraagt tot betrouwbaarheid, maar dat het vergif in de dosis zit. Vertrekkend van het gereconceptualiseerde theoretische kader konden we vaststellen dat de nieuw geïntroduceerde factoren als Team Orientation, Threat Flexibility en Efficiency, eenduidig bijdragen tot betrouwbaarheid. Ondanks het feit dat er niet zoiets is als een ideale betrouwbaarheidscocktail zijn er sterke aanwijzingen dat een gereconceptualiseerde HRT waardevol advies kan verlenen voor het ontwerp van processen die nood hebben aan hoge betrouwbaarheid. Dezelfde conclusie kan getrokken worden wanneer de vergelijking gemaakt wordt tussen teams. Contextuele en structurele dimensies (bv. teamgrootte, werklast en tijdsbesteding) blijken immers een belangrijke modererende invloed te hebben op de betrouwbaarheid van een team.

Endnotes

1 In this thesis, more than once we rely on metaphors to gain insights in the objects of our study. "*The dangers of metaphorical reasoning are well known. They provide tools for explanation, giving us insights rather than understanding, and insights can often prove illusory. They must be considered points of departure for the reasoning process rather than points of arrival*" (Boisot & Cohen, 2000, p. 123). Philosophy of Science has since long been studying the duality between empiricism and rationalism. We refer to the Heraclitus-Parmenides debate elsewhere in this thesis. Also Charles S. Peirce attributed to this debate by introducing the notion of abduction. He called this "*borrowing of metaphors from other disciplines*" and described *"how it can be used creatively to form a new explanatory hypothesis*" (Longstaff, 2003, p. 9).

2 "*These days, the business of Banking is risk management*" Dennis Westherstone, Retired JP Morgan chairman (BT, 2005).

3 A general denominator for reliability could be system effectiveness. This system effectiveness consists of different properties like: (1) Reliability; (2) Availability; (3) Reparability; (4) Maintainability; (5) Serviceability; (6) Design adequacy; (7) Capability; (8) Dependability; (9) Human reliability and (10) Environmental effect (Prasad, Hwang, Kuo, & Tillman, 2001, p. 7-8).

4 A FIT is equivalent to one failure per billion device hours.

5 Also from a practitioner's perspective, this nuance can be important. In the US Military, for instance, failure is defined in terms of a *Class A mishap* or failure, where there is loss of life, or property damages exceeding one million dollars. This is what in other context hardly would be called a failure, but more a disaster(Sullivan & Beach, 2003).

6 One of the first findings in this general area was that front line operators are not usually the perpetrators of catastrophes because catastrophes require the resources no single individual has at his or her demand (Roberts, 2005, p. 157).

7 Translated from French : '*la fiabilité se distingue de la sûreté nucléaire car elle désigne la capacité d'un matériel ou d'une installation d'assurer sa fonction prévue sans défaillance. Elle est, pour une partie du système ou pour le système, la probabilité de non-panne*'.

8 A model in which the combined effect of several factors is the sum of the effects that would be produced by each of the factors in the absence of the others (http://www.biology-online.org/dictionary/Additive model).

9 For example, the rate of production of new guidance materials and rules by the European Joint Aviation Regulators is substantially increasing. More than 200 new policies, guidance documents, and rules are created each year even though the safety of global commercial aviation has been at a plateau of 1 x 10–6 for years. Because little is known about which rules or new guidelines are truly linked to safety levels, the system is purely additive: Old rules and guidance material are never discarded or removed (Amalberti et al., 2005, p. 760).

10 Holes are not static for several reasons. They may represent individual human actions - so a human error will be represented as a hole in this model. They may represent procedural failings that may only arise under certain environmental circumstances (e.g. when the team of people involved in carrying out a procedure is under-strength). They may represent transient software faults that are corrected automatically when the system state is re-computed.

11 Citation retrieved from Weick et al. (Weick, Sutcliffe, & Obstfeld, 2005, p. 418) but checked against original.

12 With this 'all-seasons' denomination, we mean an organizational *Gestalt* that is capable of dealing with changing conditions in an automatic or semi-automatic manner. One should compare such a design and behavior to an experienced mountain-hiker and his gear. He/She is someone who has the situational awareness to sense what weather it is now and who – by taking into account the weather it has been in the past (an hour ago, last week, same time last year, …) – will be able to develop a kind of feeling for the weather he is facing in the (near) future. The design of his clothes should be such that without changing his outfit should allow him to cope with hot and cold, dry or wet weather. The material should be GORE-TEX®-like, since that fabric allows sweating (warmth release) but also protects for cold (warmth collecting); it is also impermeable enough to protect for the rain, but still it is light enough not to hinder free movement. Besides, featuring all these qualities it still is fashionable and appealing. Bringing this Gore-Tex metaphor to the field of reliability studies and organizational reliability, we state that organizations should be more Gore-Tex-like in their design and more mountain hiker-like in their behavior.

13 "*The ideas about complex systems were not developed by any one field and were not accepted overnight. Indeed, they remain controversial in some disciplines and in their application to some issues. These new ideas are all slightly different and there are no bright lines between them. They include: complexity theory, chaos theory, complex adaptive systems, general systems theory, nonlinear systems, self-organizing systems, and far-from-equilibrium systems*" (Longstaff, 2003, p. 14).

14 For the record: the Information Technology Infrastructure Library (ITIL) which will be dealt with in the description on the Incident Management Process, might be considered an example of such best-practices, although ITIL is more about a process-oriented framework than a stress of good practices themselves.

15 Therefore it might be wiser to talk about 'Lessons Observed' instead of 'Lessons Learned'.

16 It is quite interesting to see the parallel between absorbing downside complexity via requisite variety and Barnett and Pratt's (2000) autogenic crisis induction.

17 The key finding is that members of the organization deal with the problem of requisite variety by reducing a large number of combat missions to a limited number of basic-action categories (i.e., 15 meta-scripts), with missions configured as particular combinations of meta-scripts. Subsequently, each mission is accompanied by reliability feedback, also construed in terms of the same metascripts, thus stimulating ongoing learning and resulting in continued development of available variety in operators. Jointly, therefore, this strategy reduces inequalities of requisite vs. available variety by adjusting at both ends (Dov & Gil, 2003, p. 853).

18 We argue that variety tends to increase unless there is a dedicated policy to prevent this. Examples of such policies can be found in big five consultant firms and other international high potential hiring companies who systematically are engaging the same applicant profiles.

19 Boisot and Child refer to 'organisms' whereas we have narrowed this scope to 'organizations'. We feel we are entitled to do so because of these authors deal with organizations in the remainder of their article.

20 In case of the NPP the more accurate term is 'Maintenance & Repair Process'. Although it fully corresponds with the notion of incident management, it is not used because of the typicality of the term 'incident' in the nuclear energy industry where it has a negative connotation. In Banking the term incident has a far more neutral meaning.

21 We use the label High Reliability Theory for sake of convenience. At this point we do not wish to make a statement in the discussion on whether HRT is a theory or merely a metaphor or a school of thought - or like critics say: class(es) of thought.

22 Examples of complex systems include the weather and the spread of disease in a population (Longstaff, 2003, p. 15).

23 'The effect of adding something to the system (an infected person or the air disturbed by a butterfly flapping its wings) may diffuse unevenly throughout the system because the other components of the system are not evenly distributed, or the force doing the distribution is not equally strong throughout the system" (Longstaff, 2003, p. 15).

24 For a comparison: Simon (1962, p. 468) roughly describes system complexity as one made up of a large number of parts that interact in a non-simple way.

25 Elsewhere we deal with the question whether HRT really is a theory in the scientific sense.

26 Plural High Reliability Organizations (HROs).

27 Another working definition can be found in Sullivan & Beach (2003): "*A state that an organization seeks to achieve whereby the attainment of specified requirements are consistently achieved through the expeditious use of its resources over time. These organizations have a mean time between failure approaching infinity*".

28 The faculty members of the project team are T. R. LaPorte, K. H. Roberts, and G. I. Rochlin, University of California, Berkeley; D. M. Rousseau, Northwestern University; and Karl Weick, University of Texas.(at that time) (Roberts & Rousseau 1989, p. 139).

29 We call them HRO archetypes.

30 This is in line with other but related research from the Weick branch on Loose Coupling. We refer to the Loose Coupling Framework by Orton and Weick (Orton & Weick, 1990) and the voice of causation.

31 For example, Ichniowski, Shaw, and Prennushi (1997), in their study of the influence of HR practices (like) have found a positive impact of these same constructs on organizational reliability.

32 Worth noting is that the mindfulness concept was first brought to maturity by Langer (Langer, 1989), something which is acknowledged by the Michigan school (Weick et al., 1999).Remarkably, Langer, in her later writings (Langer & Moldoveanu, 2000), does not refer to Weick.

33 Having the bubble. The bubble is U.S. Navy lingo for maintaining a big picture view of operations (Roberts & Rousseau 1989, p. 135).

34 "The data suggests there is some evidence for improving reliability, perhaps through organizational means. Three of the refineries classified "more complex" experienced no RQs during the period 1993-97.All were operated by the same corporation. We do not know if this is the result of some systematic and deliberate effort to under-report such accidents, or if other factors, possibly organizational in nature are involved. Additional work is planned to determine if organizational factors were involved in the atypical reliability of the three refineries" (p. 23). On my request for information (an e-mail to Eli Berniker), no answer has come.

35 We make a distinction between first generation authors like Rochlin, La Porte, Roberts, Schulman, Consolini and Weick; second generation writers like Sutcliffe and Vogus, and third generation writers, like De Bruijne. Among this last category we put ourselves. The first generation initiated HRO research, either at Berkeley or Michigan; the second generation still has direct and strong links with the first generation – for instance because they are their former PhD students. The third generation has followed a trail independent from the original thinkers, even though some have been brought in contact with them in a later stage of their initial HRO research. The idiosyncrasy of the third generation is that they have the freedom to build on the work of their predecessors without being intellectually tributary. Today, the three generations continue to publish simultaneously, not only resulting in an eclectic mix of styles, approaches, domains and cases, but also in a cross-fertilization between them. This offers interesting perspectives for an original and fundamental development of the discipline.

36 We do not imply that HRT scholars do not offensively defend the position the take when challenged by NAT scholars, but they clearly have chosen a not-juxtaposing perspective to both approaches.

37 In this dissertation we use 'SenseMaking' in that spelling to discern it from the colloquial 'sense making'.

38 In this respect, it should be mentioned that this thesis' core is HRT, not SenseMaking. The limited elaboration of *theory* on SenseMaking should be seen from that perspective.

39 This basic premise applied to all technologies is one of the basic building blocks of the Socio-Technical Systems (STS) approach (Bostrom & Heinen, 1977, p. 18).

40 A common background in education, training, hiring policies and (organizational) culture will have something to do with this.

41 Substantial parts of this section are borrowed with permission from Muhren (2006).

42 Substantial parts of this section are borrowed with permission from Smals (2006).

43 These figures are based on the year 2004.

44 To put these numbers into perspective: in 2001, the average American household used about 10,000 kWh (0.01 GWh) in a year [EIA, 2005].

45 The operational factor for the reactors over the period 1985-2005 averaged about 88%

46 For an elaboration of SenseMaking as an interpretive research methodology, we refer to research we have conducted in the Democratic Republic of Congo (DRC). In the DRC, Development-aid organizations often face situations characterized by complexity and uncertainty, with crises occurring anytime. These networked organizations need to make sense of their crisis environment inter- and intra-organizationally. In a first paper (Muhren, Van Den Eede, & Van de Walle, 2008b) we attempt to reveal the "black box" of information processing activities by relying on SenseMaking as a methodology and as the object of research. In particular, this research aims at studying intuitive information processing activities in ongoing crisis situations, one of the most extreme contexts in which discontinuity is the rule and continuity the exception. The authors argue that this SenseMaking approach offers valuable insights for the design of information systems for crisis response and management (ISCRAM). This paper describes an interpretive case study methodology as it was applied to discover SenseMaking episodes in the daily work of humanitarian relief actors in the ongoing crisis of the Democratic Republic of the Congo. In a second paper (Muhren, Van Den Eede, & Van de Walle, 2008a) we addresses three research issues: Firstly, we use the theory of SenseMaking as a lens to study how organizations process information inter-organizationally and intra-organizationally. Secondly, we identify the need of more sensible information systems to support SenseMaking in crisis environments. Thirdly, we argue why the inverse of the journal title – i.e. Development for IT – bears some promising perspectives for the expansion of the IS research discipline in the developed world as well. For this triple research objective, we take the extreme conditions under which humanitarian and development actions take place as a starting point. We

have used an interpretive approach to this research by interviewing senior managers of organizations for humanitarian aid and development in the Democratic Republic of the Congo.

47 At the Bank we were assisted by Joris Hens, Geert Thoelen and Thomas Huyghe from Vlekho Business School and Willem Muhren from Tilburg University. At the NPP we got the help from Koen Ceuppens (Vlekho Business School) and Raphaël Smals (Tilburg University). All of them were master students preparing their master thesis in the HRT field under our primary (Vlekho Business School) or secondary (Tilburg University) supervision.

48 In addition to the 19 and 23 interviews, respectively at the Bank and at the NPP, in total 9 more interviews were conducted with the objective to study the degree and way of coupling in both organizations. This data is analyzed and discussed in the Epilogue to this dissertation. As such these interviews are no inherent part of the research thread.

49 Idem.

50 For an elaboration of the use of GSS in this research/the Bank Case study, we refer to Rutkowski, Van de Walle and Van Den Eede (2006) in which we presented results from a field study at our Bank Case on the use of Group Support Systems (GSS) as a novel approach to identify operational risks in the Bank's Incident Management Process. Our research has lead to two important findings. First, we found that the use of GSS enables unique risks to reach a short-list of crucial risks to be managed by the Bank. Second, the use of GSS allowed an isolated minority of senior managers to implicitly influence the decision of the group on the risk management decision process. Parts from this title is taken from the same source.

51 The name 'building blocks ' originated from the methodological approach we took to the writing of this thesis but was afterwards confirmed by an article by Roberts and Bea (2001) where these authors also use the term 'building blocks' to denote what composes the typicality of HROs

52 The necessity to get a 'buy-in' from the organizations in question was a constant preoccupation. Senior management continuously asked for their 'Return on Investment': what will it cost them (especially in time) and what will they get back for it. The organizations under study were triggered by the prospect of being presented a 'photo of who they are'.

53 The complete data preparation logbook is available from the author upon simple request.

54 In this it resembles SenseMaking properties of retrospection, enactment etc.

55 This conclusion is supported by confirmatory factor analysis through Structural Equation Modeling (SEM) (Wijnen, Janssens, De Pelsmacker, & Van Kenhove, 2002, p. 247), which results yielded no support for the theoretical underpinning of High Reliability Theory or SenseMaking. Confirmatory factor demonstrated that the multidimensionality of High Reliability theory does not hold. Data shows that a multidimensional theory, consisting out of five sub-constructs yield no better results than a single-construct one. A testing of the constructs shows that multicollinearity between the items is extremely high. Confirmatory factor analysis demonstrates that the construct of Deference to Expertise does not attribute to the model. Hence our choice not to totally rely on the constructs as they are described in literature and not to build on confirmatory factor analysis, but to rely on exploratory factor analysis in order to find those constructs that are best/better suited for use in our analysis.

56 Other researchers have built on these categories as well. Sullivan & Beach (2003), for instance, in their study on a conceptual model to balance risk by HRO Success Factors stemming from these five categories.

57 Smart et al. (2003) illustrated how recent tragedies have been shown to be threatening to the medium-term sustainability of organizations designed and developed solely on the basis of short-term efficiency gain.

58 The resulting hypothesized curvilinear relationship was supported by comprehensive worldwide data on 264 functional departments of two multinational corporations.

59 For sake of completeness: A Type III error occurs whenever the right solution is given to the wrong problem. A Type IV error is defined as "the incorrect interpretation of a correctly rejected hypothesis", comparable to "a physician's correct diagnosis of an ailment followed by the prescription of a wrong medicine".

60 Original definition from Albert, S. & Whetten, D. (1985). Organizational Identity. In: Research in organizational behavior, Vol. 7, pp. 263-295.

61 The other property is the use of plausibility as the fundamental criterion of SenseMaking (Weick et al. 2005).

62 Originally In: Gililand, S. W. & Day, D. V. (2000) Business management. F. T. Durso, ed. Handbook of Applied Cognition. Wiley, New York, pp. 315–342. Mezias, J. M., W. H. Starbuck. 2003. Managers and their inaccurate perceptions: Good, bad or inconsequential? *British J.* Management.

63 The other relevant elements of the structural dimension are discussed under the Deference to Expertise issue.

64 Note that this relates to Simon's notion of nearly decomposable systems (1962).

65 One such experience was gained from an exercise for the Bank Case to build a multiple regression model capable of explaining reliability. The outcome of this regression analysis is beyond the scope of this dissertation. It has been reported upon in a separate internal memo.

66 Myers and McPHee found that one crew-level variable—crew reliability—affected and modified the influence of tenure, proactivity, involvement, acculturation, and trust on members' commitment.

67 Lin and Carley have observed more of an increase in resource-to-people links than in people-to-people links; whereas, most researchers have focused on change in people-to-people links (Krackhardt and Stern 1988; La Porte and Consolini 1991) (Lin & Carley, 2001).

68 In the same research, Lin and Carley also found that this kind of organizations "switched their designs toward more complex designs, not necessarily more rigid designs. The number of restructurings in resource access structure is eight times as large as the number of restructurings in organizational authority structure. This suggests that organizations are more likely to maintain existent lines of communication and authority during crises but are more likely to restructure who has access to what and responsibility for what. Of all the 69 organizations, only 31 did not alter either their organizational authority or resource access structures." (Lin & Carley, 2001)(p. 26-27).

69 What should be feasible however, is to compare the relative reliability of both processes, e.g. by normalizing the values for reliability. But then again, this allows intra-case comparison, but no inter-case assessment.

70 We have reached a similar conclusion while conducting a linear regression analysis on the Bank data. Multicollinearity diagnostics revealed that several independent variables were a linear function of other independent variables, in casu Commitment to Resilience vis-à-vis the other HRT constructs.

71 In the NPP incidents are so rare that there is hardly something to learn from. The community of international nuclear production facilities has found a way of sharing their experiences amongst each other. Another way of compensating for the lack of learning is exercising by means of incident scenarios in a simulator setting.

72 http://www.css.edu/users/dswenson/web/TWAssoc/adhocracy.html

73 This is in line with other but related research from the Weick branch on Loose Coupling. We refer to the Loose Coupling Framework by Orton and Weick (Orton & Weick, 1990) and the voice of causation.

74 With this 'all-seasons' denomination, we mean an organizational Gestalt that is capable of dealing with changing conditions in an automatic or semi-automatic manner. One should compare such a design and behavior to an experienced mountain-hiker and his gear. He/She is someone who has the situational awareness to sense what weather it is now and who – by taking into account the weather it has been in the past (an hour ago, last week, same time last year, …) – will be able to develop a kind of feeling for the weather he is facing in the (near) future. The design of his clothes should be such that without changing his outfit should allow him to cope with hot and cold, dry or wet weather. The material should be GORE-TEX®-like, since that fabric allows sweating (warmth release) but also protects for cold (warmth collecting); it is also impermeable enough to protect for the rain, but still it is light enough not to hinder free movement. Besides, featuring all these qualities it still is fashionable and appealing. Bringing this Gore-Tex metaphor to the field of reliability studies and organizational reliability, we state that organizations should be more Gore-Tex-like in their design and more mountain hiker-like in their behavior.

75 Weick recounting an incident that happened to a small Hungarian detachment on military maneuvers in the Alps (Weick, 1983, p. 48-49): "Their young lieutenant sent a reconnaissance unit out into the icy wilderness just as it began to snow. It snowed for two days, and the unit did not return. The lieutenant feared that he had dispatched his people to their deaths, but the third day the unit came back. Where had they been? How had they made their way? Yes, they said, we considered ourselves lost and waited for the end, but then one of us found a map in his pocket. That calmed us down. We pitched camp, lasted out the snowstorm, and then with the map we found our bearings. And here we are. The lieutenant took a good look at this map and discovered to his astonishment that it was not a map of the Alps, but of the Pyrenees."

76 For an elaboration on the concept of networked reliability see De Bruijne (de Bruijne, 2006)